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Science Focus

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A PATHOLOGICAL LIAR

The search for
THE EDGE OF THE UNIVERSE

FUTURE CITIES

GREEN, FRIENDLY AND CLEAN:
HOW WE COULD REIMAGINE
URBAN LIFE AFTER THE PANDEMIC

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Psychology
How false memories shape criminal court cases

Space
First look at the new map of the Milky Way

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FROM THE EDITOR

There's a song that epitomises my thoughts about life in the city. It goes "New York, I love you. But you're bringing me down". I imagine this sums up the love affair many of us have with the cities we live in, even if it's not the Big Apple. Life in the city comes at a cost. Not just the obvious one (the money it takes to keep you alive and off the street) but the toll it can take on your physical and mental wellbeing.

The pandemic, which kept us shut in our homes and taught us to work remotely, seems to have shone a harsh light on that trade-off. The air pollution, congestion, lack of green space, noise and everything in between, now seems like too high a price to pay for many. Realising this, people have started quitting their jobs and leaving the city – and in such great numbers that some are calling it the Great Resignation.

We're perhaps still too close to the pandemic to see the effect all this will have, but the powers that be seem to have taken note and, like the rest of us, are viewing this moment as an opportunity for change. Now, urban planners around the world are dreaming up new ways to improve our ageing cities, and tempt some of us to stay in them. Across the channel, Paris is planning to transform the Champs-Élysées into one enormous garden, and the city's Mayor intends to turn Parisian rooftops green and build the world's largest urban farm. Clearly, there's an appetite for change. So head to p62 to find out some of the best ways we could transform our urban landscapes.

Enjoy the issue!

Daniel Bennett, Editor

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CONTACT US

Advertising
David.DSouza@ourmedia.co.uk
0117 300 8110
Letters for publication
reply@sciencefocus.com
Editorial enquiries
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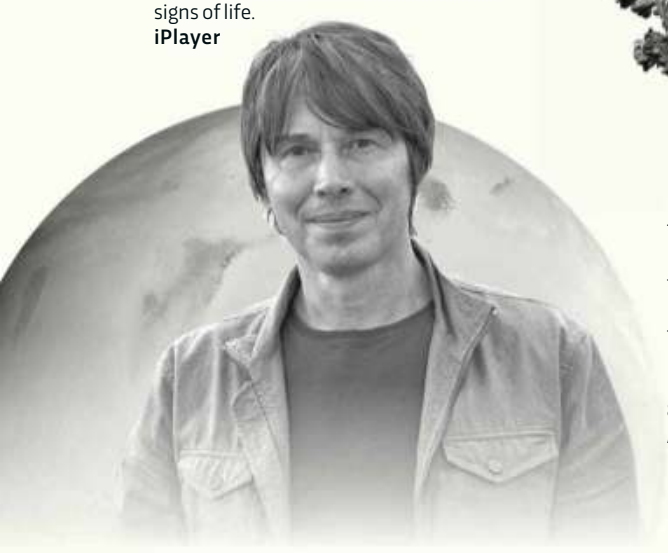
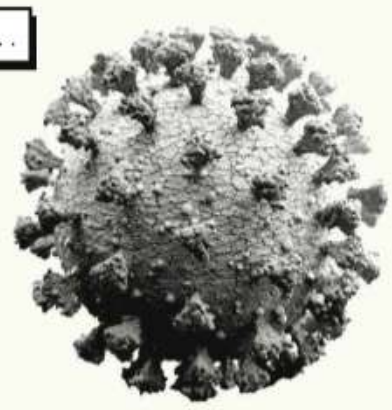
ON THE BBC THIS MONTH...

Seven Days on Mars
Brian Cox gets unprecedented access to the control room of the Mars Perseverance Rover and the Ingenuity helicopter as they explore the Martian surface looking for signs of life.
iPlayer





How COVID changed science
The pandemic put a fire under researchers and fast-forwarded traditional scientific processes. Prof Devi Sridhar takes a look at how the last two years have changed medicine for better or worse.
BBC Radio 4
8 July, 11am
Also available on BBC Sounds

CrowdScience: What is healthy hair?
We love our hair, hence the internet is awash with tips and advice for looking after your locks. But what does it really mean to have healthy hair? The CrowdScience team brushes up to find the most environmentally friendly way to keep your barnet in tip-top condition.
BBC World Service
1 July, 8:30pm
Also available on BBC Sounds

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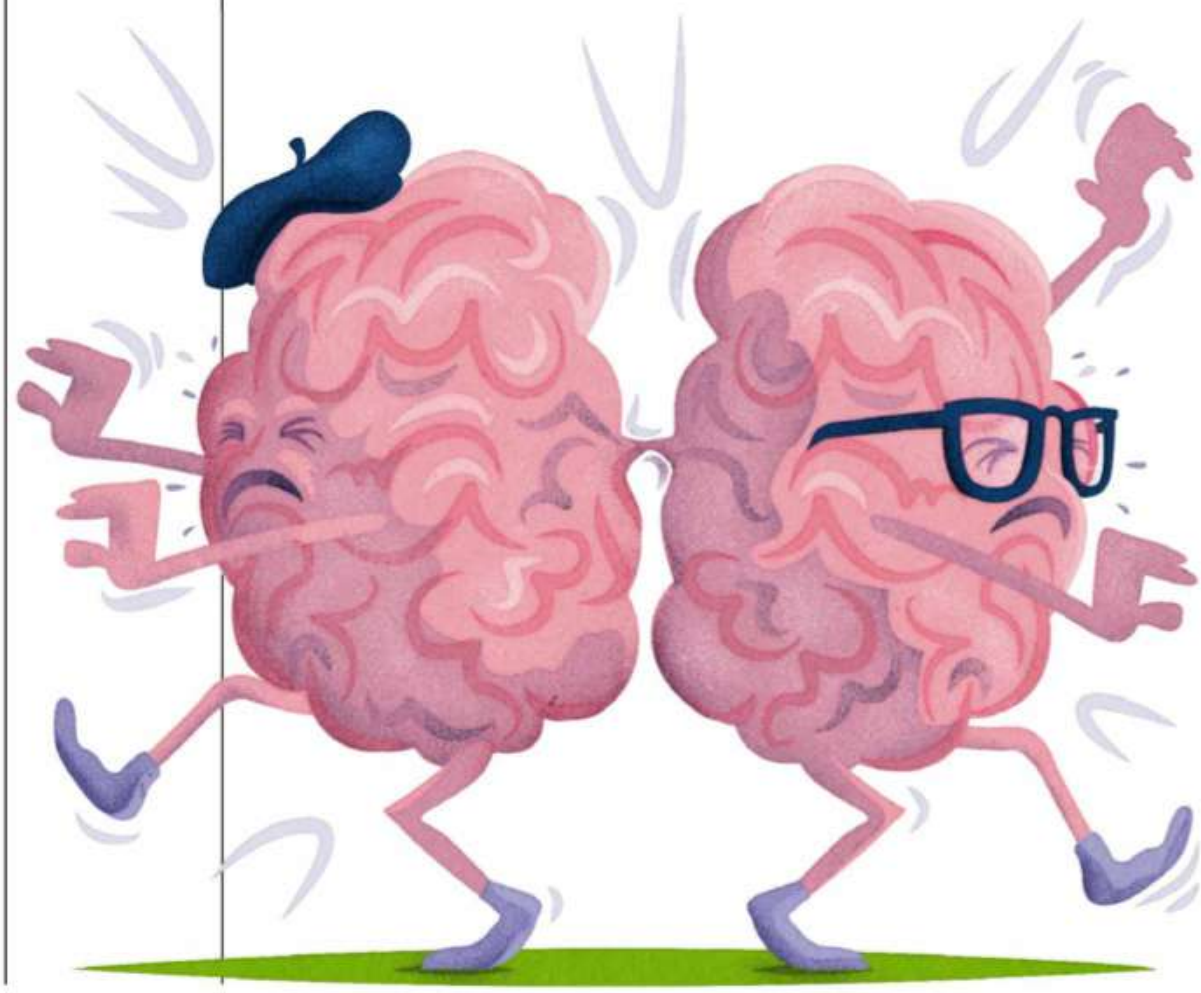

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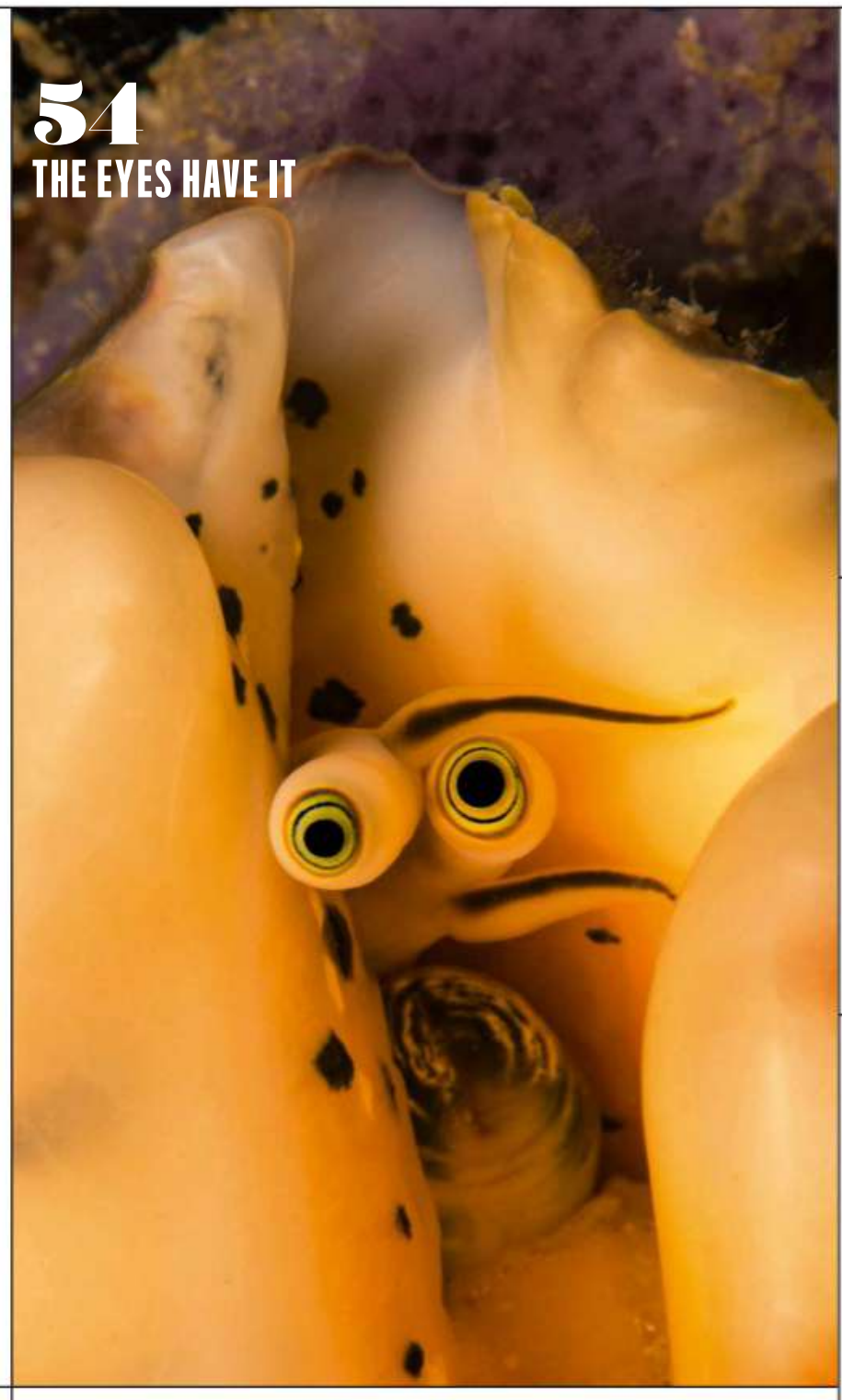

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EYE OPENER

Cold call

LONGYEARBYEN, SVALBARD

On the Norwegian archipelago of Svalbard lies this array of telecoms domes, which are in constant communication with polar-orbiting satellites.

The Svalbard Satellite Station (SvalSat) sits on a mountaintop near Longyearbyen, one of the most northern permanent settlements in the world. Built as a joint venture between NASA and the Norwegian Space Centre, the ground station is now run by Kongsberg Satellite Services. Its northern location is ideal for communication with low-altitude satellites that orbit the poles, making contact once per revolution.

However, the climate is harsh, with the highest temperature ever recorded only 21.7°C, and daily average temperatures around -4°C. So to protect them from the rain, snow and ultra-low temperatures, the receivers are encased in 'radomes'. These weatherproof, golf ball-like structures may look opaque to us, but crucially are transparent to the microwaves and radio waves that the satellites use to communicate.

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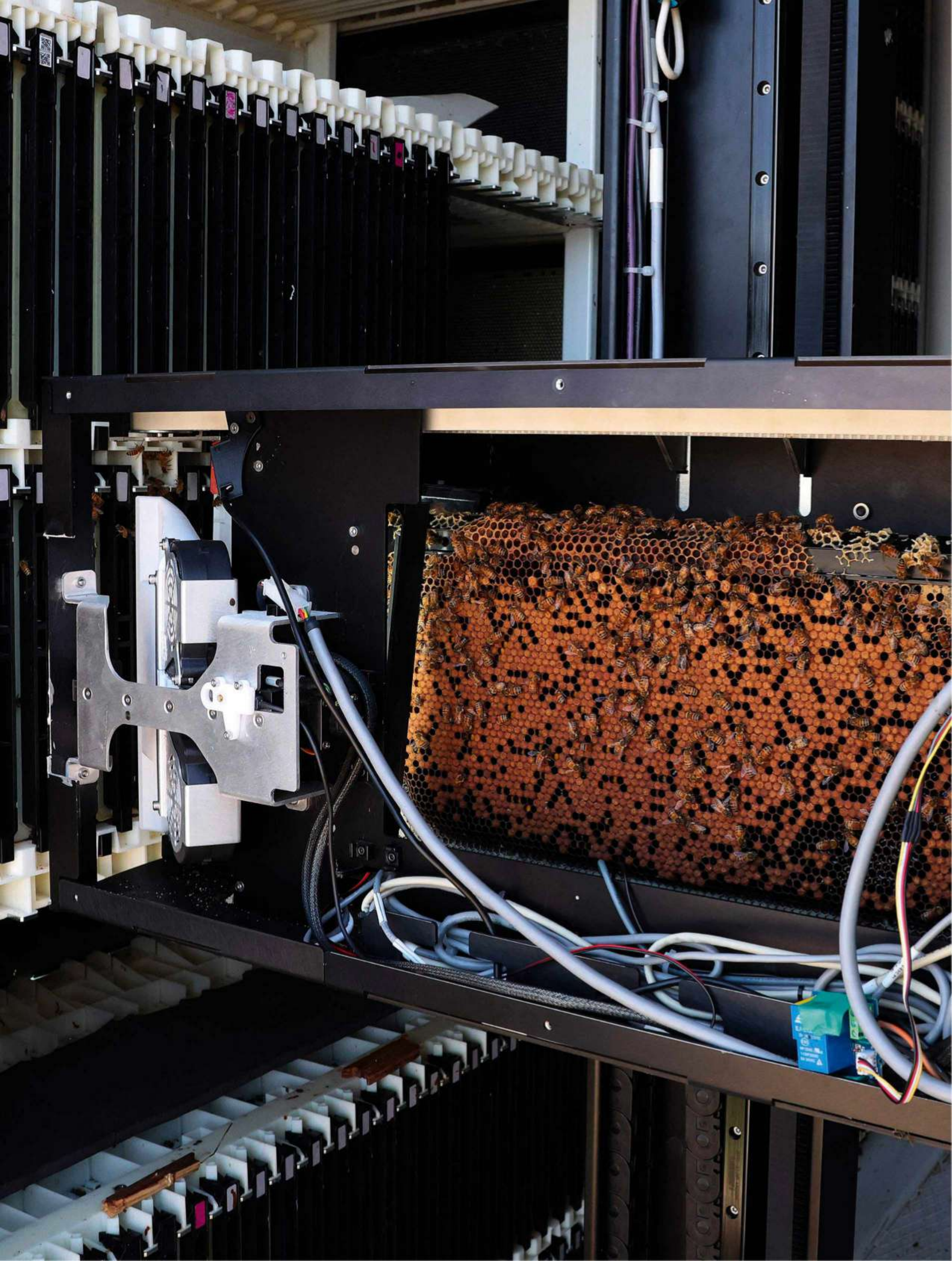

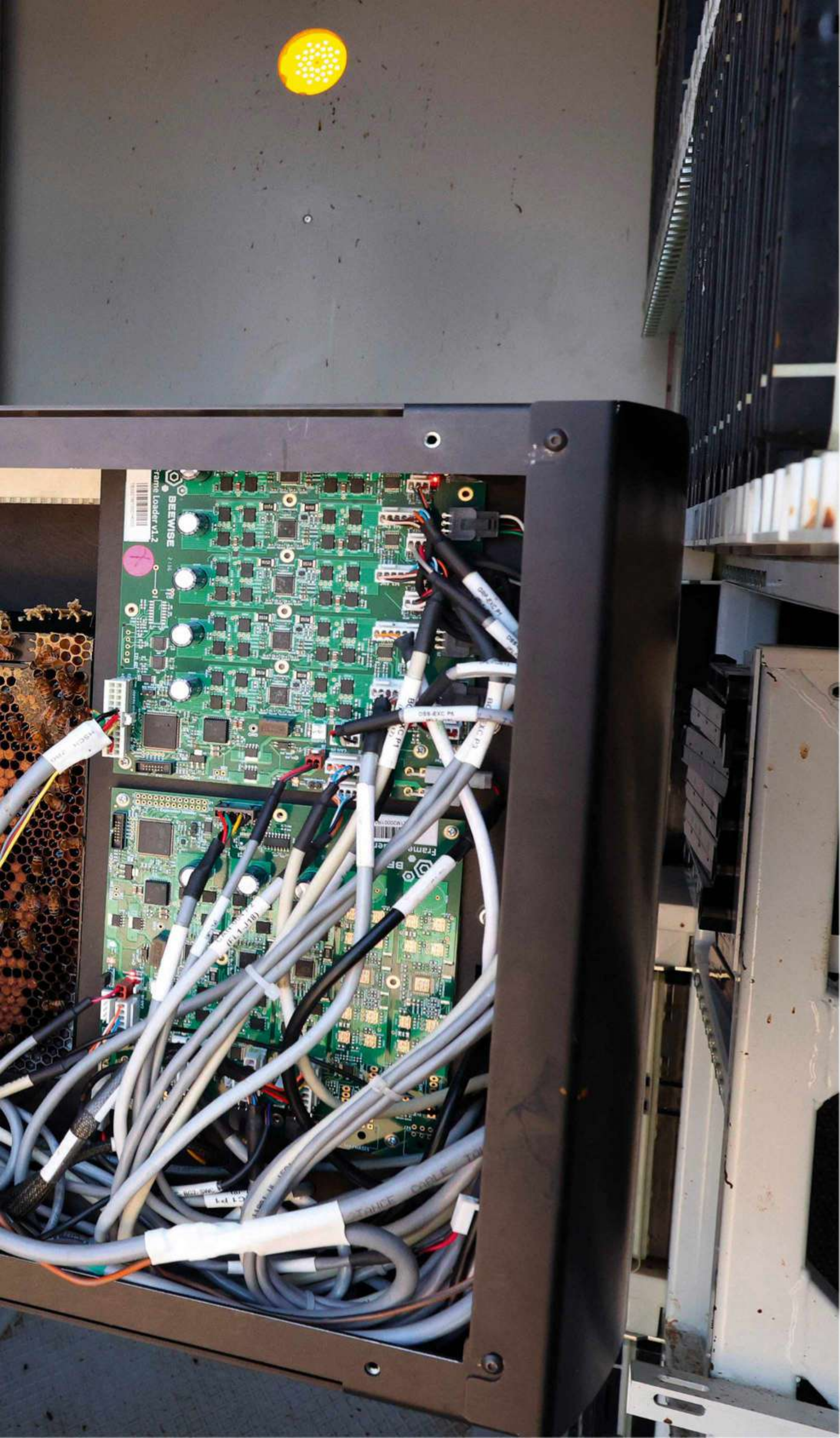

EYE OPENER

High-tech hive

BEIT HAEMEK,
ISRAEL

Pollinators keep planet Earth alive. More than 70 per cent of the vegetables, fruit, seeds and nuts that we eat are pollinated by bees. But they, like all insects, are declining in numbers, due to things like habitat loss, climate change and pesticides.

This high-tech beehive hopes to improve the health of bee colonies. Using artificial intelligence, it can keep temperature and humidity levels optimum and monitor for deadly pests or other problems, like a colony about to swarm.

The autonomous hive, created by Beewise, can hold up to 48 colonies at once, which is between one and two million bees.

"It's as if every bee had her own beekeeper, 24/7," explains CEO Saar Safra. "Unfortunately, the number of beekeepers is dwindling. There simply isn't enough labour to address bees' needs."

But with the help of the AI hive, beekeepers can keep colonies happier, healthier and honey-er!

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EYE OPENER

Lost cities

LLANOS DE MOJOS, BOLIVIA

For centuries, legends have told of ancient cities lost in the Amazon rainforest, luring explorers and treasure seekers. Now, massive urban landscapes have been uncovered – using helicopters kitted out with the remote sensing technology LIDAR.

Hidden among the dense vegetation, a number of remarkable settlements thought to have belonged to the Casarabe Culture (AD 500 to 1400) in the Llanos de Mojos savanna forest have been digitally deforested.

The one shown here was abandoned around 600 years ago. It's about 500m long and made up of stepped platforms (dark green) upon which lie rectangular and U-shaped mounds (yellow/orange) and a conical pyramid around 200m tall (red). It's one settlement among a network that spans several kilometres.

This discovery sheds new light on the history of the Amazon basin. What was thought to be jungle wilderness turns out to have been urbanised, with a high level of sociopolitical organisation long before Western explorers arrived.

HEIKO PRÜMERS

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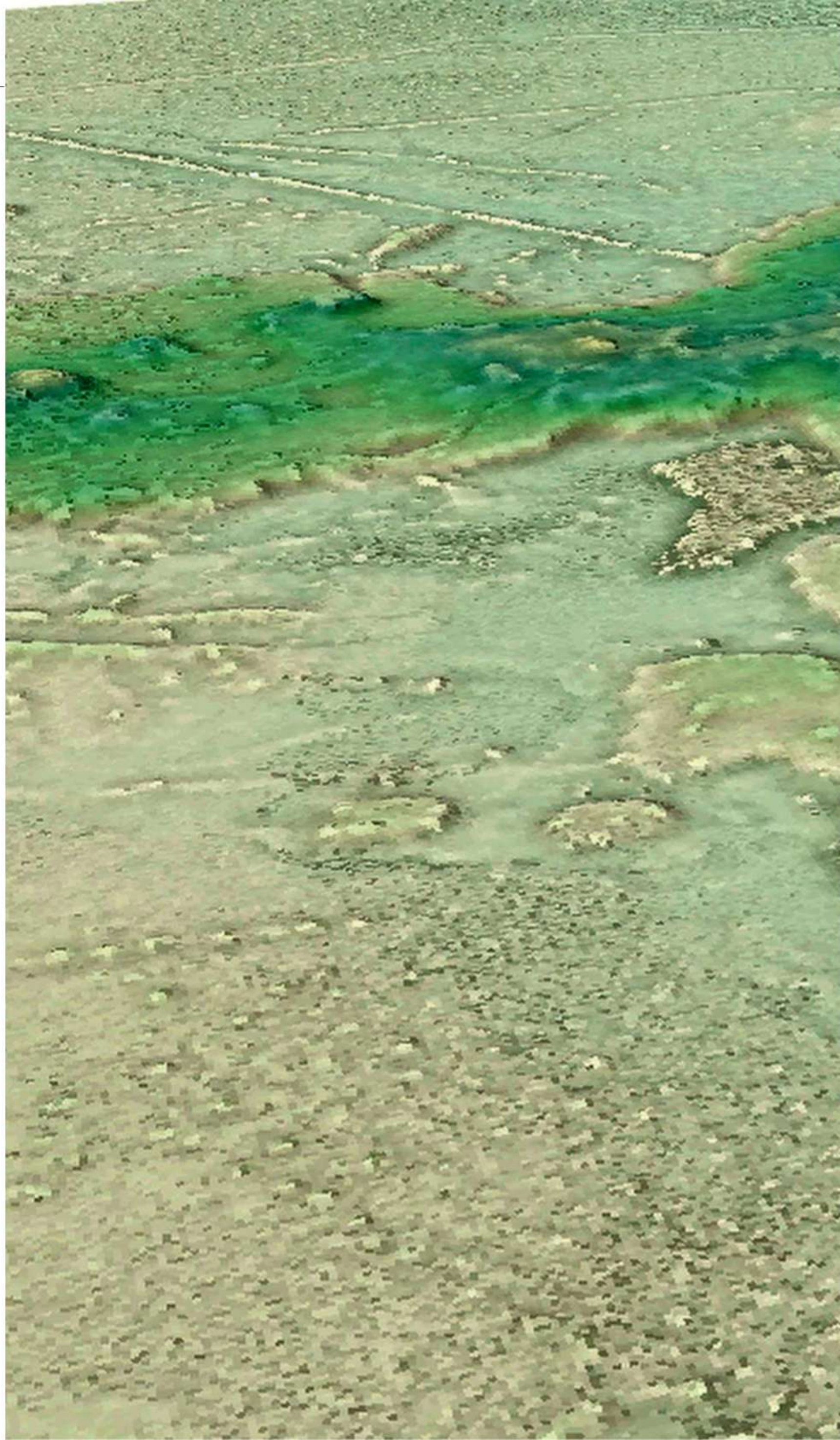

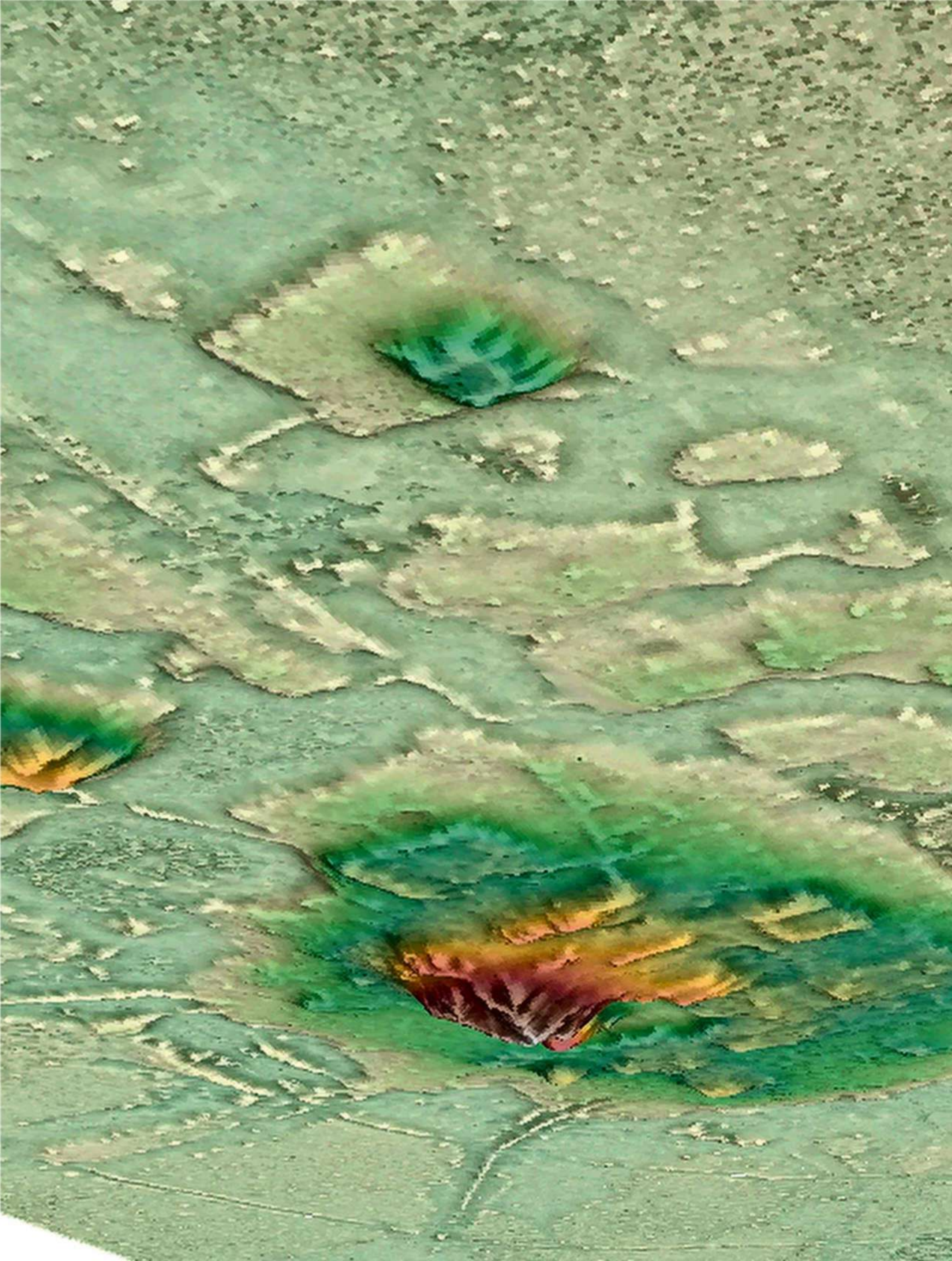

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

Dementia and autism

I was interested to read your article about damaged areas of the brain possibly explaining confusion in dementia patients (April, p21). I was diagnosed autistic when I was 38 and I noticed a lot of similarities with my own experience in relation to coping with small changes. I, along with many other autistic people, often find small changes disorientating or distressing. I would be fascinated to know whether the same areas in the multiple demand network of the brain are noticeably different in autistic people. I also struggle with multitasking and am curious whether that is related to the same area of the brain.
Lucy McAlister, via email

This exact study was not conducted with autistic people, but other researchers have identified differences in frontal areas of the brain in autistic people compared with controls. Other research has also demonstrated difficulties with 'executive control' (including multitasking and task switching) in autistic people, but it's a controversial and complex area of study because some experts believe at least some of the differences seen in autism might be due to other factors having to do with motivation and social challenges, rather than to do with cognitive impairments *per se*.
Dr Christian Jarrett, psychologist

WRITE IN AND WIN!
The writer of next issue's *Letter Of The Month* wins an **Oclean X Pro Elite Smart Electric Toothbrush**. With a speed of 42,000rpm, this electric toothbrush, complete with an easy-to-read touchscreen and 32 intensity settings, is sure to help keep your teeth clean. Plus, with 35 days of battery life, you won't need to worry about taking a charger with you on your hols. **oclean.com**

Puppy love

In the article titled 'Does Your Dog Really Love You?' (May 2022, p72), a reasonable conclusion is drawn that dogs have evolved to form a stronger attachment to humans than their wolf ancestors. However, it is also likely that the persecution of wolves has caused their evolution too, as only those wolves that were most wary of humans have survived.
David Hudson, Wiltshire

Frozen in ice?

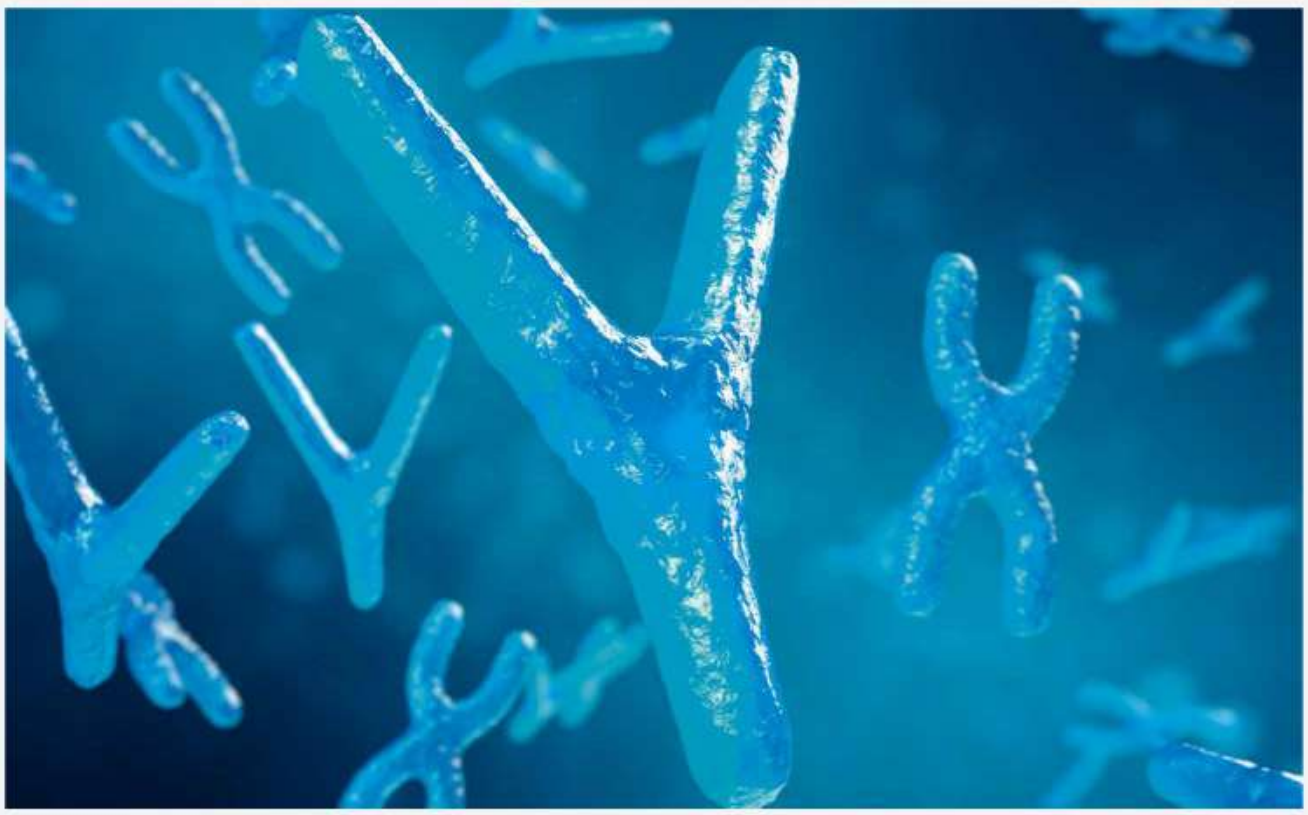
I have a theory regarding the origin of the current COVID pandemic. Is it not possible that this virus has been 'locked up' for millennia in glaciers and permafrost, which are now melting due to global warming, and releasing bugs into our atmosphere? What other atmosphere borne bugs might be released on further melting? Or am I just a crackpot (wife's words)?
Robert L Turner, Crieff

Thawing permafrost could lead to the release of viruses that have lain dormant in the frozen ground. It's a worry, but their potential for transmission is limited by there being so few people around to infect. A number of studies

Did we make wolves more wary?

"PATHOLOGICAL LIARS TELL TALL TALES AS A KIND OF UNCONSCIOUS STRATEGY TO BOOST THEIR FRAGILE SENSE OF SELF OR LOW SELF-ESTEEM"

DR CHRISTIAN JARRETT, P38



The human sex chromosomes are called X and Y

GETTY IMAGES X3

point to the most likely source of the COVID outbreak being an infected animal at the Huanan Seafood Market in Wuhan, China.
Daniel Bennett, editor

YY not?

Your interview with geneticist Turi King in the April issue says that sex is determined by the 23rd pair of chromosomes: comprising either two X chromosomes or an X and a Y. Is it possible to have the third permutation of two Ys, and if so, how would this affect gender?
Alan Thomas, via email

While the most common combination of sex chromosomes is either XX or XY, it is possible to be born with other combinations. The most common of these are Turner syndrome (where a person is born with just one X chromosome and is female(XO)), Triple-X (where someone is born with more than two X chromosomes and is female (XXX)), Klinefelter syndrome (where a male has more than one X chromosome (XXY)), and XYY syndrome (where a male is born with more than one Y chromosome).
Prof Turi King, geneticist

More than a myth

I would not be quite so hasty to conclude that "the idea that kids go crazy when it's windy seems to be no more than an urban myth" (May, p85). In my teaching days, it certainly seemed to me that children become restless and uneasy on very windy days, and was frequently corroborated by colleagues.

Here in Norfolk, I've often heard it said that horses and farm animals become anxious and confused during high winds because they lose their sense of smell. Some suggest that this is the consequence of an evolutionary response.

A creature such as a zebra on the plains of Africa would rely on its sense of smell to detect a predator lurking in the long grass. So it's easy to see how being deprived of the sense of smell could have led to distress. Perhaps a vestige of that ancient response has remained with humans to the present day.
Alan Johnson, Norfolk

THE TEAM

EDITORIAL
Editor Daniel Bennett
Managing editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Online staff writer Sara Rigby
Staff writers Alex Hughes, Holly Spanner
Editorial assistant Amy Barrett

ART
Art editor Joe Eden
Picture editor James Cutmore

CONTRIBUTORS
Claire Asher, Scott Balmer, Rob Banino, Hayley Bennett, Peter Bentley, Steve Boswell, Daniel Bright, Steve Brusatte, Verity Burns, Anson Chan, Marcus Chown, Stuart Clark, Kate Darling, Emma Davies, Russell Deeks, Ian Evenden, Christian Jarrett, Stephen Kelly, Poppy Lam, Pete Lawrence, Katie Mack, Nish Manek, Dann Mitchell, Helen Pilcher, Jenny Price, Jeremy Rossman, Helen Scales, Julia Shaw, Magic Torch, Luis Villazon, Myriam Wares.

ADVERTISING & MARKETING
Business development manager David D'Souza
Newstrade manager Rob Brock
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane

MOBILE
Head of apps and digital edition marketing Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION
Production director Sarah Powell
Production coordinator Georgia Tolley
Ad services manager Paul Thornton
Ad designer Julia Young

PUBLISHING
Publisher Andrew Davies
Group managing director Andy Marshall
CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING
Chair, editorial review boards Nicholas Brett
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Director, magazines and consumer products Mandy Thwaites
Compliance manager Cameron McEwan
UK publishing coordinator Eva Abramik
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DISCOVERIES

“To observe salamanders in the air is a bit unexpected in and of itself”

Christian Brown on salamanders **p20**

SPACE

A WHOLE LOTTA SHAKIN’ GOING ON

Gaia space probe spots starquakes across the Milky Way **p16**

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BUGS IN OLD GUTS

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All patients remain tumour-free two years after trial **p23**

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Cress grown in regolith returned by Apollo missions **p24**

ANIMAL BEHAVIOUR

RATS TO THE RESCUE

Rodents trained to seek out earthquake survivors buried under rubble **p26**

APOPO

Boldly going where dogs and drones can’t go... rats are being trained to find people trapped in collapsed buildings **p26**

SPACE

'TSUNAMI-LIKE' STARQUAKES AMONG THE DISCOVERIES IN THE MOST DETAILED SURVEY OF THE MILKY WAY EVER

The European Space Agency's Gaia spacecraft's latest data release has revealed a treasure trove of insights about our home galaxy

Since its launch in 2013, the spacecraft has been on a mission to create the most accurate multidimensional map of the Milky Way ever. Now, with its third data release, Gaia has published a raft of new findings based on observations of almost two billion stars and other cosmological bodies.

"Unlike other missions that target specific objects, Gaia is a survey mission. This means that while surveying the entire sky with billions of stars multiple times, Gaia is bound to make discoveries that other more dedicated missions would miss," said Gaia scientist Timo Prusti.

"This is one of its strengths, and we can't wait for the astronomy community to dive into our new data to find out even more about our galaxy and its surroundings than we could've imagined."

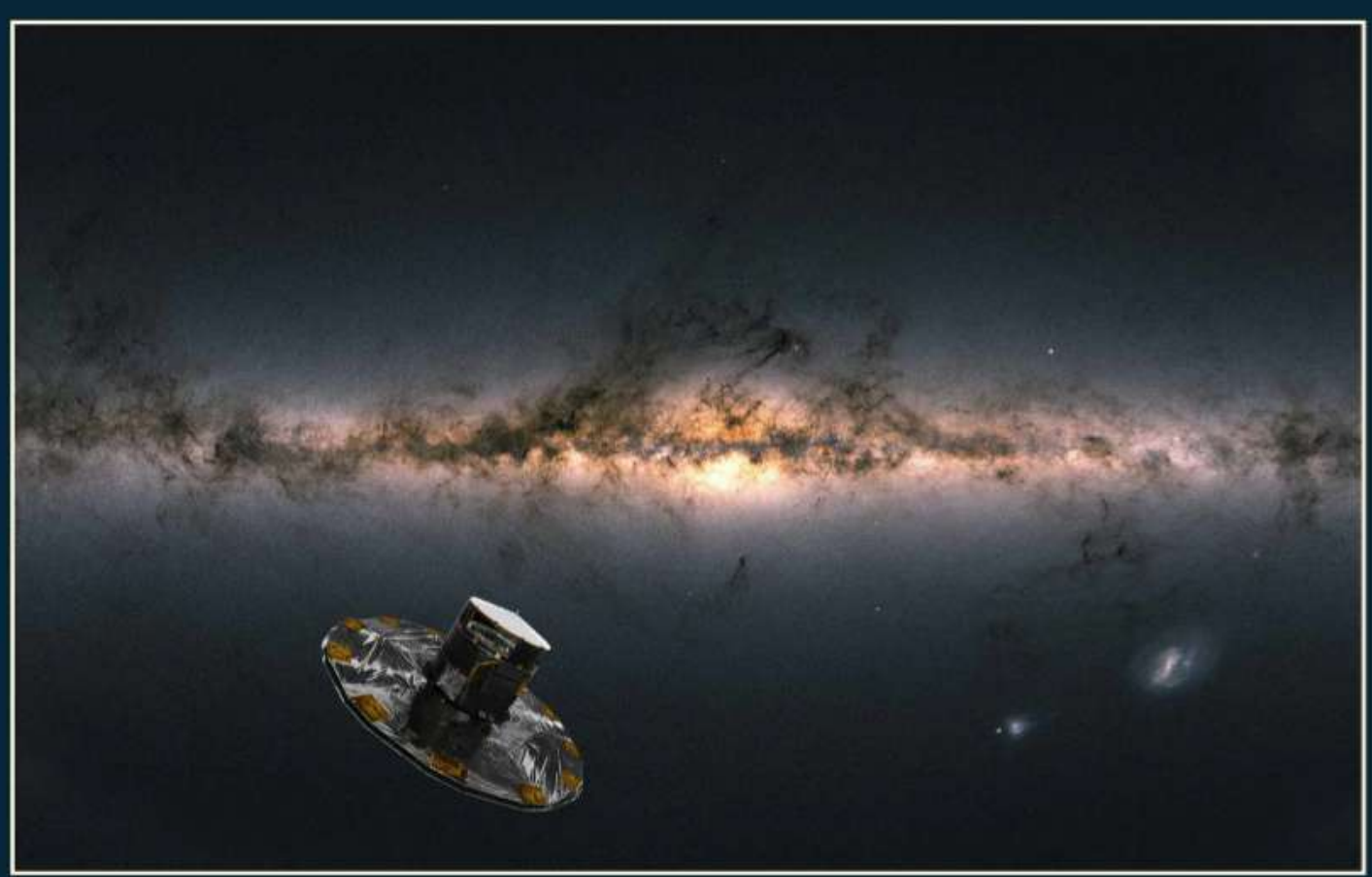
STARQUAKES

One of the headline observations in the latest release is of unusual oscillations, known as starquakes, that ripple along the surface of stars – something Gaia was never originally designed to detect.

Starquakes occur in magnetars – a type of small, dense neutron star with some of the strongest magnetic fields in the Universe. These magnetic fields cause huge stresses in the stars' crusts, which produce rippling earthquake-like effects.

Gaia had previously observed starquakes with radial oscillations that cause stars to swell and shrink periodically, while maintaining their spherical shape. The newly spotted starquakes move across the surface like giant tsunamis, however, making them trickier to spot. But these unusual and unfamiliar starquakes are of great interest to astronomers, so they're keen to catch sight of more of them.

"Starquakes teach us a lot about stars, notably their internal workings. Gaia is opening a goldmine for 'asteroseismology' of massive stars," said Gaia scientist Conny Aerts of KU Leuven in Belgium.



An artist's impression of ESA's Gaia satellite during its mission to survey the Milky Way. The background shows the total brightness and colour of over 1.8 billion stars seen by Gaia, details of which were disclosed in its third data release

ESA/D DUCROS, ESA X2

STELLAR 'DNA'

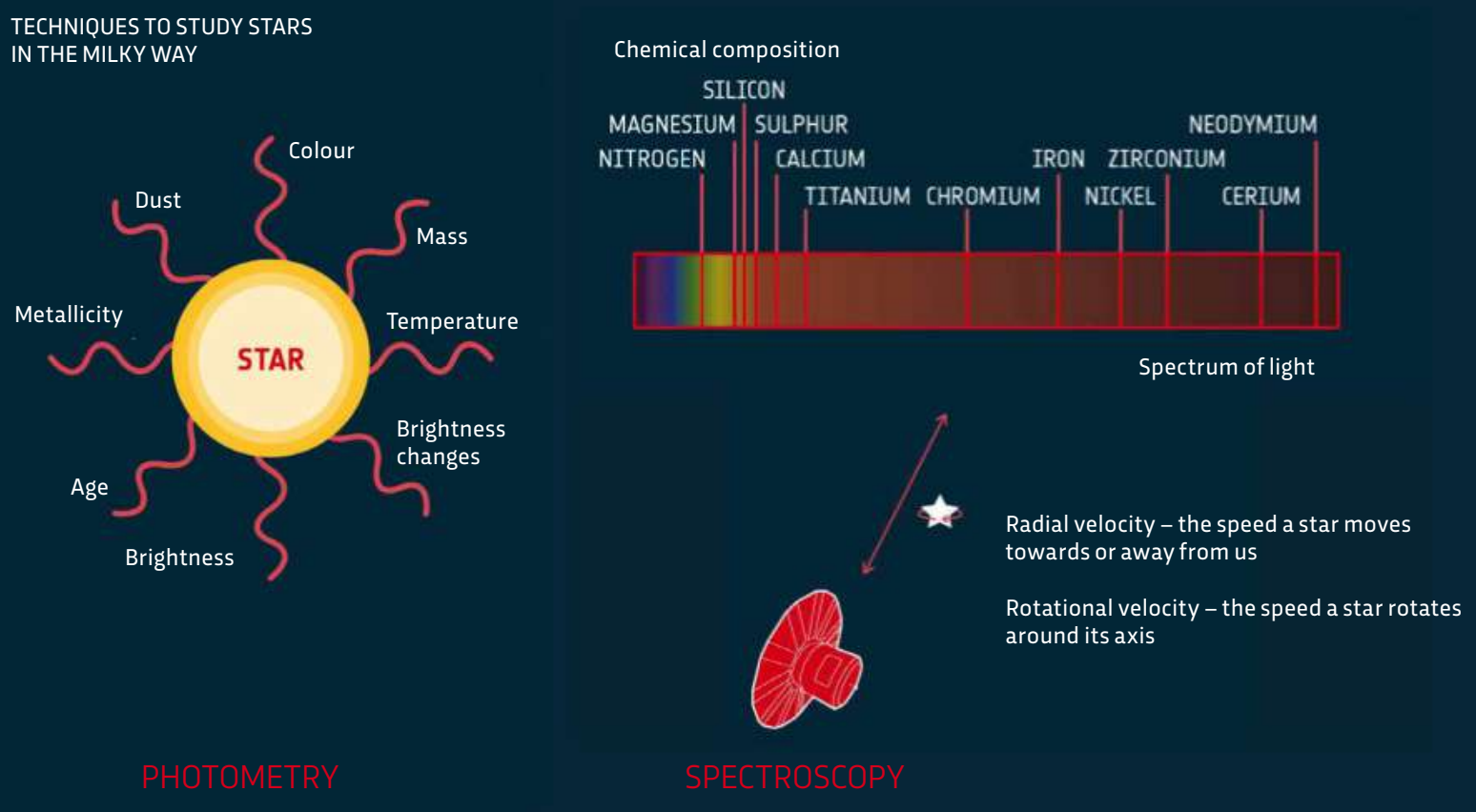
Gaia's latest release contains detailed information on almost two billion stars, including their temperatures, ages and chemical compositions.

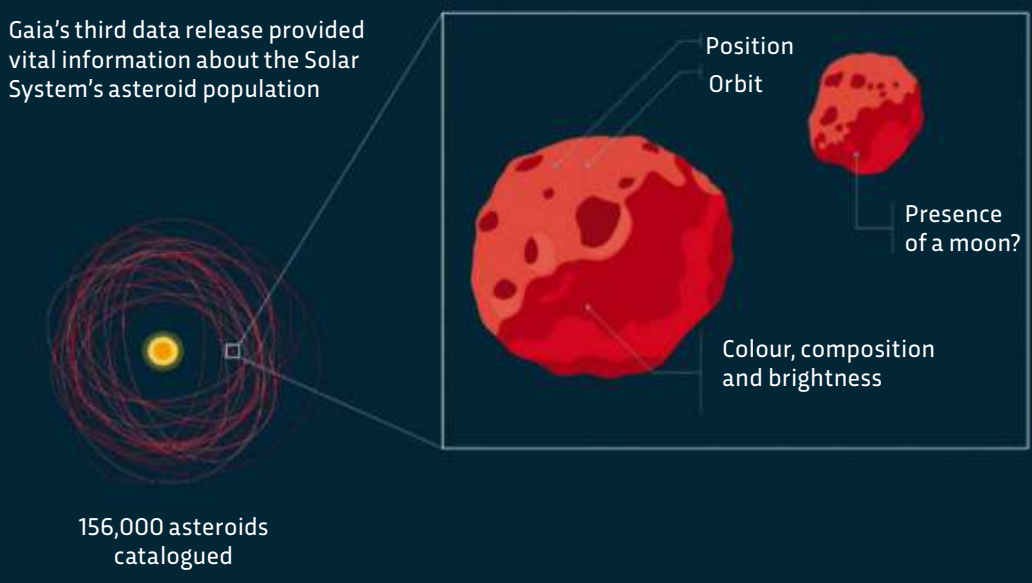
Astronomers can learn a lot about stars by studying their chemical compositions, which, similar to DNA, provides clues as to their origins and lifecycles. A star's chemical composition can be determined through spectroscopy – a technique that analyses the light a star produces to figure out what chemicals are present inside it.

Data from Gaia shows that some stars in the Milky Way are made from primordial material while others, such as the Sun, are composed of material made in previous generations of stars.

The early Universe consisted mainly of light elements, such as hydrogen and helium. The heavy elements were created in stars that formed later, as the lighter elements collapsed under gravity. When stars die, they release these heavier elements, which go on to form new stars – essentially seeding their 'DNA' into successive generations.

"Our galaxy is a beautiful melting pot of stars," said Gaia scientist Alejandra Recio-Blanco of the Observatoire de la Côte d'Azur in France. "This diversity is extremely important, because it tells us the story of our galaxy's formation. It reveals the processes of migration in our galaxy and accretion from external galaxies. It also clearly shows that our Sun, and we, all belong to an ever-changing system, formed thanks to the assembly of stars and gases of different origins."




Gaia's third data release provided vital information about the Solar System's asteroid population
Position
Orbit
Presence of a moon?
Colour, composition and brightness
156,000 asteroids catalogued

ASTEROIDS

The Gaia scientists have also used the new data to compile a catalogue of more than 156,000 asteroids. It's the most accurate catalogue of asteroids ever composed and contains information about their orbits and compositions.

The asteroids observed by Gaia include the main-belt asteroids; Trojan asteroids that orbit Jupiter; 24 members of the asteroids found in orbit beyond Neptune; and asteroids pulled into the centre of the Solar System due to gravitational attraction of various planets, which includes so-called near-Earth objects (NEOs). None of the currently known NEOs are in danger of striking Earth in the coming decades, Gaia researchers say.

ARCHAEOLOGY

4,500-YEAR-OLD POO FOUND NEAR STONEHENGE SHOWS NEOLITHIC BRITONS WERE RIDDLED WITH PARASITES

The bugs were also present in dog poo found at the site, suggesting that prehistoric humans fed leftovers to their pet pups

Ancient faeces found at Durrington Walls, a Neolithic settlement close to Stonehenge, contain the eggs of parasitic worms, researchers at the University of Cambridge and UCL have found.

The settlement dates back to around 2,500 BC and is believed to have been home to the people who erected the famous monument.

Archaeologists analysed 19 pieces of ancient faeces, or coprolites, from the site that have been preserved in a mass dung heap for 4,500 years. Five samples – one from humans and four from dogs – were found to contain eggs of capillariid worms. These parasites live in the lungs or liver of their hosts.

The finding suggests that the Neolithic humans were eating undercooked offal and feeding the leftovers to their dogs, the researchers say.

"This is the first time intestinal parasites have been recovered from Neolithic Britain, and to find them in the environment of Stonehenge is really something," said lead author Dr Piers Mitchell from the University of Cambridge.

"The type of parasites we find are compatible with previous evidence for winter feasting on animals during the building of Stonehenge."

When excavating the dung heap, the archaeologists unearthed fragments of pottery, rudimentary stone tools and more than 38,000 animal bones.

Although 90 per cent of the bones were from pigs, the most likely source of the parasite is cows, as capillariid worms typically infect ruminants.

Archaeological evidence suggests that Durrington Walls was occupied during the second stage of the construction of Stonehenge, when the iconic 'trilithons' – a pair of huge vertical stones topped by a third horizontal stone – were erected. The seasonal residents of Durrington Walls are thought to have carried out the work.

"This new evidence tells us something new about the people who came here for winter feasts during the construction of Stonehenge," said Prof Mike Parker Pearson from UCL.

"Pork and beef were spit-roasted or boiled in clay pots, but it looks as if the offal wasn't always so well cooked."

Neolithic humans feasted on pork and beef... but maybe could've done with cooking it for longer

FOOD IN BRITAIN

Mesolithic 10,000–4000 BC
The people of this period were hunter-gatherers who lived on species native to Britain including wild animals such as birds and fish, and leaves, roots and fruit from plants.

Neolithic 4000–2200 BC
Domestic animals such as cattle, pigs and sheep, were introduced from the continent.

Bronze Age 2200–800 BC
The spread of arable farming led to the cultivation of crops such as beans, peas and spelt wheat.

IRON AGE 800 BC–AD 43
Britons began keeping and eating chickens.

Roman Period AD 43–410
The Roman invasions vastly increased the variety of food in Britain, adding game meats such as rabbit and pheasant, vegetables such as leeks and onions, and herbs such as garlic, pepper, basil and thyme.

Middle Ages 410–1485
Sugar was brought to Britain by western Europeans during the Crusades.

Tudor Period 1485–1603
Further trading with Europe and exploration of the Americas by the Spanish saw the introduction of potatoes, rice and turkey.

Stuart Period 1603–1714
Oranges, coffee and tea were widely available to Britons by the mid-17th Century.

Modern Era 1714–
Food is imported from all over the world for consumption by the British.

GETTY IMAGES X2

CLIMATE

WARMER WEATHER DUE TO CLIMATE CHANGE IS EATING AWAY AT OUR SLEEP

If current trends continue, we could be missing out on an hour of sleep a week by the end of the century

Rising temperatures due to climate change are negatively impacting our sleep, a study carried out by a team at the University of Copenhagen has found.

The findings suggest that by the year 2099, higher temperatures will lead to us losing 50 to 58 hours of sleep per year – roughly one hour per week.

To make the discovery, the team analysed data collected from accelerometer-based sleep-tracking wristbands that had been shown to match up with self-reported measures of wakefulness and sleep in previous studies.

The dataset included seven million individual records taken from more than 47,000 adults from 68 countries across all continents except for Antarctica.

The team found that on nights when the ambient temperature exceeded 30°C, people slept 14 minutes less on average. The likelihood of someone getting less than the recommended seven hours of sleep a night also increased as temperatures rose.

"In this study, we provide the first planetary-scale evidence that warmer-than-average temperatures erode human sleep. We show that this erosion occurs primarily by delaying when people fall asleep and by advancing when they wake up during hot weather," said first author Kelton Minor of the University of Copenhagen.

The researchers also found that the effect is even more pronounced for residents from lower-income countries, as well as older adults and females.

Every night, when we go to sleep, our bodies shed heat into the surrounding environment by dilating our blood vessels and increasing blood flow to our hands and feet. In order for this process to occur efficiently, the surrounding environment needs to be cooler than our bodies, otherwise our sleep becomes interrupted.

The researchers now hope to expand the study to take in data from an even larger number of participants, especially more vulnerable populations such as those who live in the world's hottest and poorest regions.

"In order to make informed climate policy decisions moving forward, we need to better account for the full spectrum of plausible future climate impacts extending from today's societal greenhouse gas emissions choices," said Minor.

Hot weather can rob us of our sleep

ZOOLOGY

GLIDING SALAMANDERS MOVE LIKE SKYDIVERS

The amphibians live high in the canopies of giant redwood trees in California

Wandering salamanders twist and turn their bodies like human skydivers to control their falls, a study carried out at the University of South Florida has found.

The behaviour was first observed by the study's lead author Christian Brown, who noticed the animals' unusual leaps as he was handling them while cataloguing their population in Humboldt and Del Norte counties, California.

The researchers say the animals use their skydiving skills to steer towards the branches of the giant redwoods and stay away from ground-based predators.

To further study the animals' aerial manoeuvres, the researchers placed them and three other species of salamander into a small wind tunnel and filmed their movements using a high-speed digital camera. They found that the wandering salamanders (*Aneides vagrans*) were able to maintain a stable gliding posture by moving their tails and legs in a manner similar to human skydivers, allowing them to slow the speed of their falling by up to 10 per cent.

"To observe salamanders, which are generally associated with ponds and streams, in the air is a bit unexpected in and of itself. Most surprising to us was the exquisite level of control that the more arboreal salamanders had in the vertical wind tunnel. Wandering salamanders were especially adept and seemed to instinctively deploy skydiving postures upon first contact with the airstream," said Brown.

"These salamanders were not only able to slow themselves down, but also used fine-scale control in pitch, roll, and yaw to maintain upright body postures, execute banking turns, and glide horizontally."

The finding is particularly surprising as the salamanders don't have any webbing or flaps on the surface of their skin to help them parachute and glide, the researchers say. This could potentially mean that other animals may also have hidden skydiving abilities.

The team now plans to use 3D modelling software to further investigate how the salamanders are able to generate lift. They also hope that the findings will help attract attention to *A. vagrans*, which are currently classified as near threatened on the International Union for Conservation of Nature Red List.

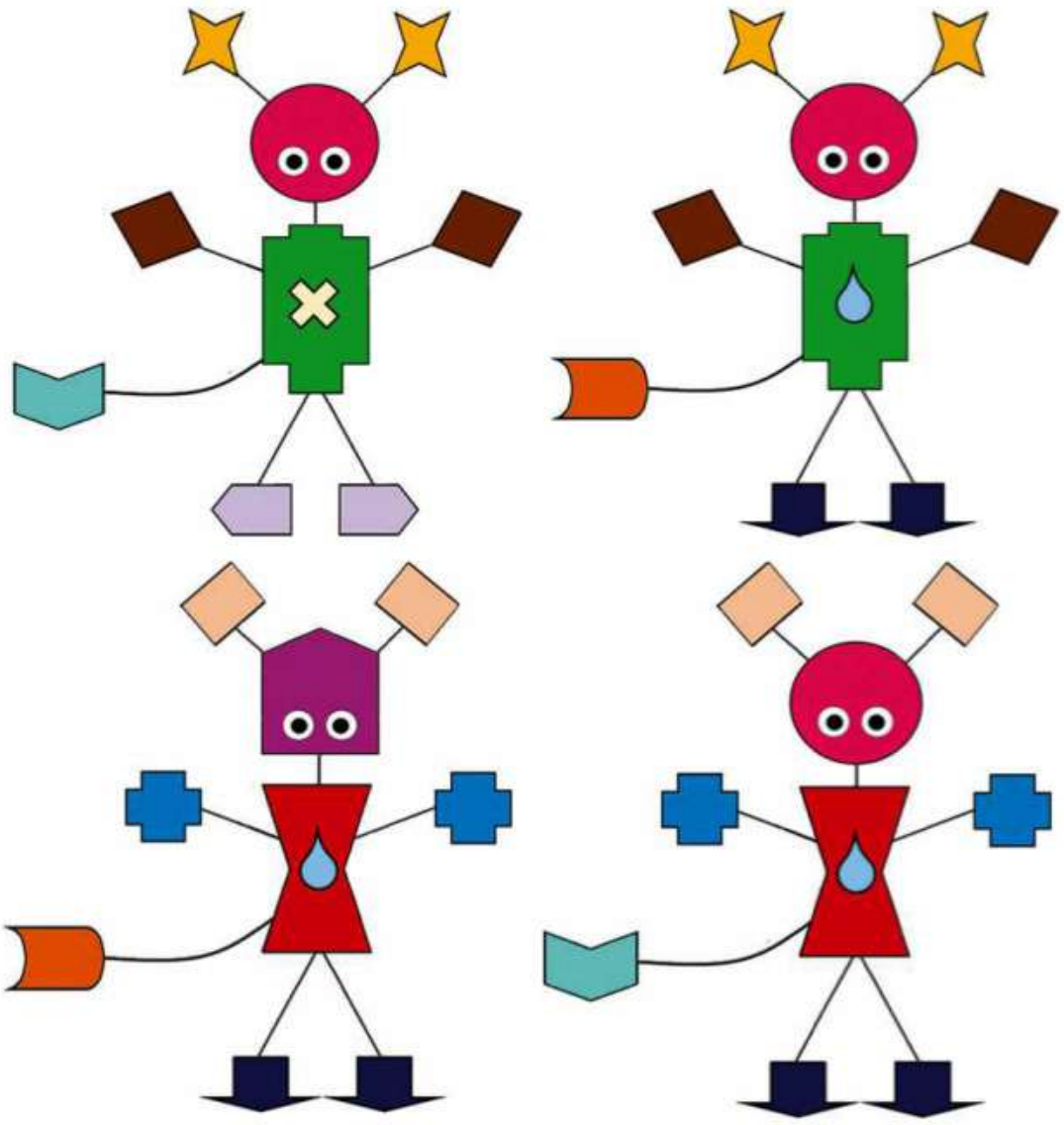
"Scientists have barely scratched the surface in studying the redwood canopy ecosystem and its unique fauna"

"Scientists have barely scratched the surface in studying the redwood canopy ecosystem and the unique fauna it has shaped through evolutionary time," said Brown.

"With the climate changing at an unprecedented rate, it is vitally important that we collect more data on animals like wandering salamanders so we may better understand, protect and preserve this delicate ecosystem."

The wandering salamander twists and turns its body in the air, so it can exert some control over its fall

ALISON NORTHUP/INATURALIST.ORG/WIKIPEDIA, OHIO STATE UNIVERSITY



As part of the study, participants had to play games with imaginary creatures called 'flurps' and 'jalets'

BRAIN

SIMPLY ENCOUNTERING NEW OBJECTS CAN PRIME THE MIND FOR LEARNING

New research is one of the first to provide evidence for a phenomenon known as 'latent learning'

This may sound like every lazy student's dream, but we are able to acquire new knowledge without actively trying, a study carried out at Ohio State University has confirmed.

The study is one of only a handful to provide experimental evidence that people can learn about objects they aren't even trying to understand, simply by being exposed to them.

The Ohio State University team designed a series of computer game experiments to test the participants' latent learning abilities. In the first experiment, the researchers had the participants play a simple game involving colourful imaginary creatures. However, they didn't tell them that each creature belonged to one of two categories based on different features such as hand and tail colour.

They then moved the experiment on to an 'explicit learning' phase, where the researchers told the participants that the creatures belonged to one of two categories, 'flurps' or 'jalets', and taught them how to identify them.

The ability of this group to identify the flurps and jalets was then compared to a control group who had previously been asked to play a similar game involving a different set of imaginary creatures, without the defining characteristics.

"We found that learning was substantially faster for those who were exposed to the two categories of creatures earlier on than it was in the control group participants," said lead author and postdoctoral researcher Layla Unger.

"Participants who received early exposure to Category A and B creatures could become familiar with their different distributions of characteristics. Such as, those creatures with blue tails tended to have brown hands, and creatures with orange tails tended to have green hands. Then when the explicit learning came, it was easier to attach a label to those distributions and form the categories."

The team then carried out a second experiment to determine the degree to which a fresh set of participants was able to learn to recognise the difference between flurps and jalets during the early exposure phase.

This time, they were asked to hit a specific key as quickly as possible when creatures placed in the centre of the screen jumped to the left or right. They were not told that one type always jumped to the left and the other always jumped to the right, however.

If they were able to learn this during the initial stage of the experiment, then their reaction times would be expected to speed up as they would be able to identify the type of creature before it jumped.

This wasn't the case – they still required the follow-up explicit learning phase to accurately identify the creatures. However, they were able to identify the creatures more quickly than the control group, indicating that some latent learning had taken place.

"The exposure to the creatures left participants with some latent knowledge, but they weren't ready to tell the difference between the two categories. They had not learned yet, but they were ready to learn," said Unger.

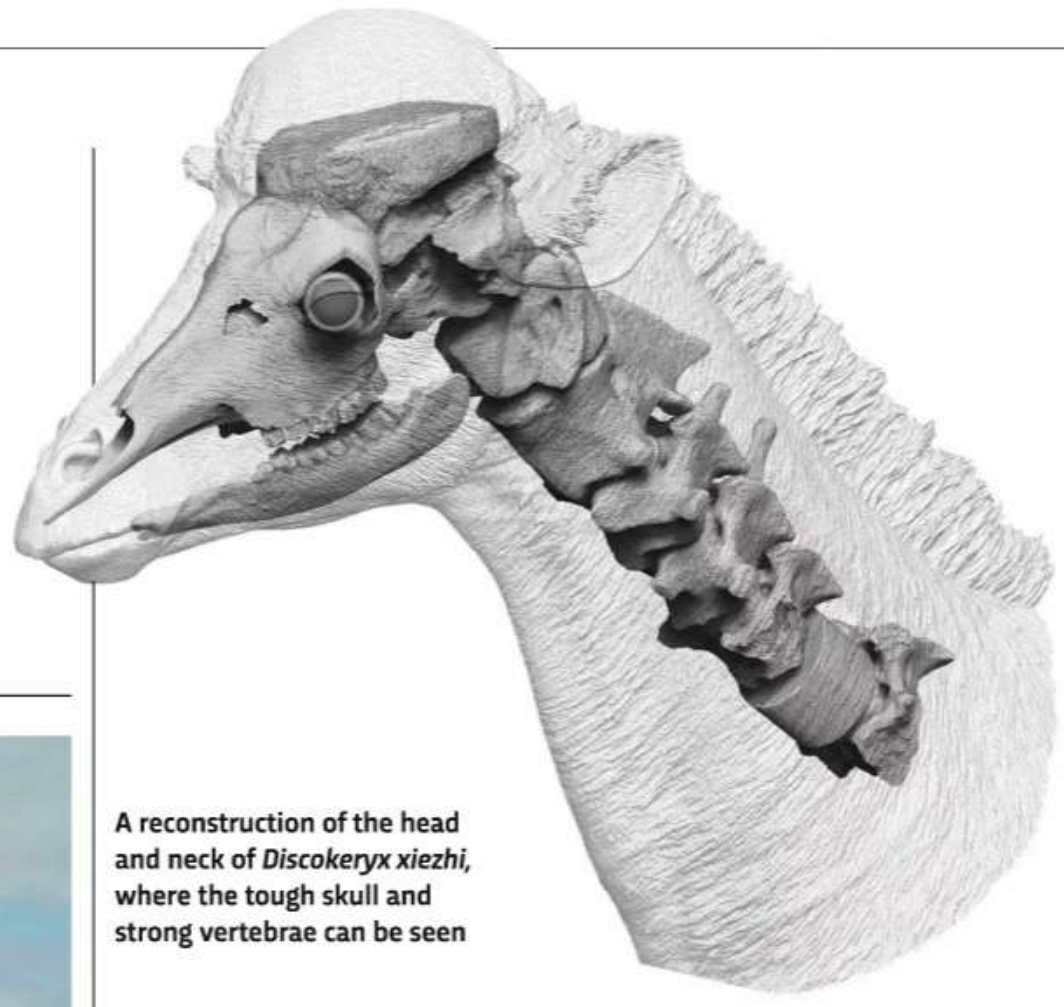
"It has been very difficult to diagnose when latent learning is occurring," added the study's co-author Prof Vladimir Sloutsky.

"But this research was able to differentiate between latent learning and what people learn during explicit teaching."

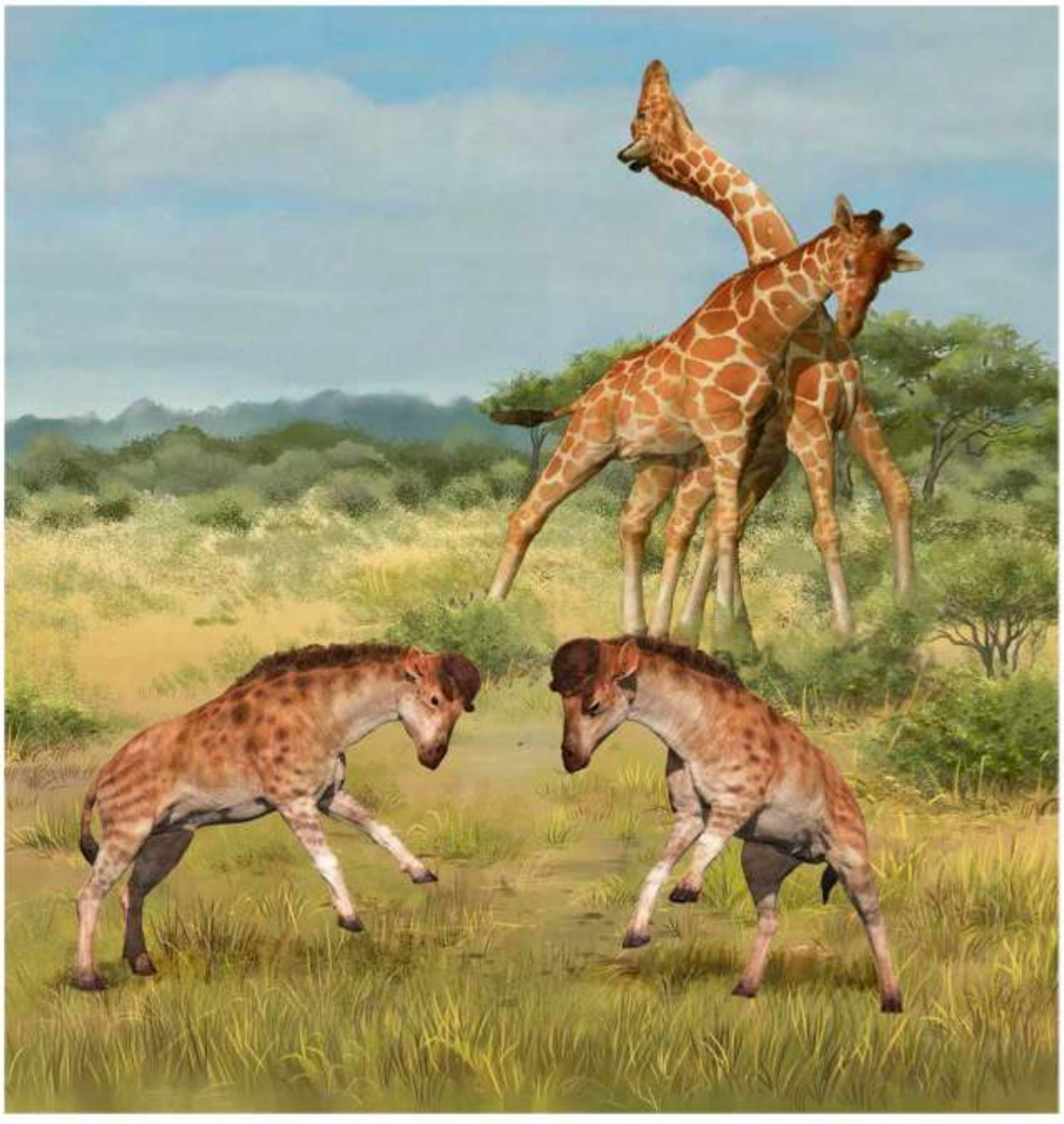
ZOOLOGY

DID GIRAFFES EVOLVE THEIR LONG NECKS FOR COMBAT?

Fossil of ancient giraffe relative reveals skull and neck bones that are highly adapted for throwing brutal headbutts



A reconstruction of the head and neck of *Discokeryx xiezhi*, where the tough skull and strong vertebrae can be seen



Discokeryx xiezhi (in the foreground) had anatomy adapted for high-speed head-to-head combat. This behaviour may have led to the evolution of long necks in modern giraffes (in the background)

Giraffes are widely thought to have evolved such long necks in order to feed on high foliage that other animals found difficult to reach. But it may actually have been competition for mates that gave them this unique adaptation, researchers at the Institute of Vertebrate Paleontology and Paleoanthropology of the Chinese Academy of Sciences have found.

Giraffes' necks can measure two to three metres in length. During courtship competitions, the animals fight by using their long necks to whip their heavy skulls, which are topped with hard, horn-like ossicones, into their opponents.

Animals with longer necks are able to land more powerful blows on their opponents, making them more likely to win fights for mates. It's also believed giraffes with longer necks are deemed to be further up the social hierarchy.

Now, a 17-million-year-old fossil of *Discokeryx xiezhi*, an ancient relative of modern giraffes, found in Junggar Basin, Xinjiang, western China, suggests that this behaviour may be what led to the animals evolving their trademark long necks.

Though its neck is much shorter than that of modern giraffes, analysis of the fossil shows that *D. xiezhi* had an incredibly complex series of joints between its head and spine, along with a hard, disc-shaped ossicone on its head that made it particularly adapted for high-speed, head-to-head impacts.

They found this structure was far more effective at absorbing impacts than that of other modern animals adapted to heavy head impacts, such as musk oxen.

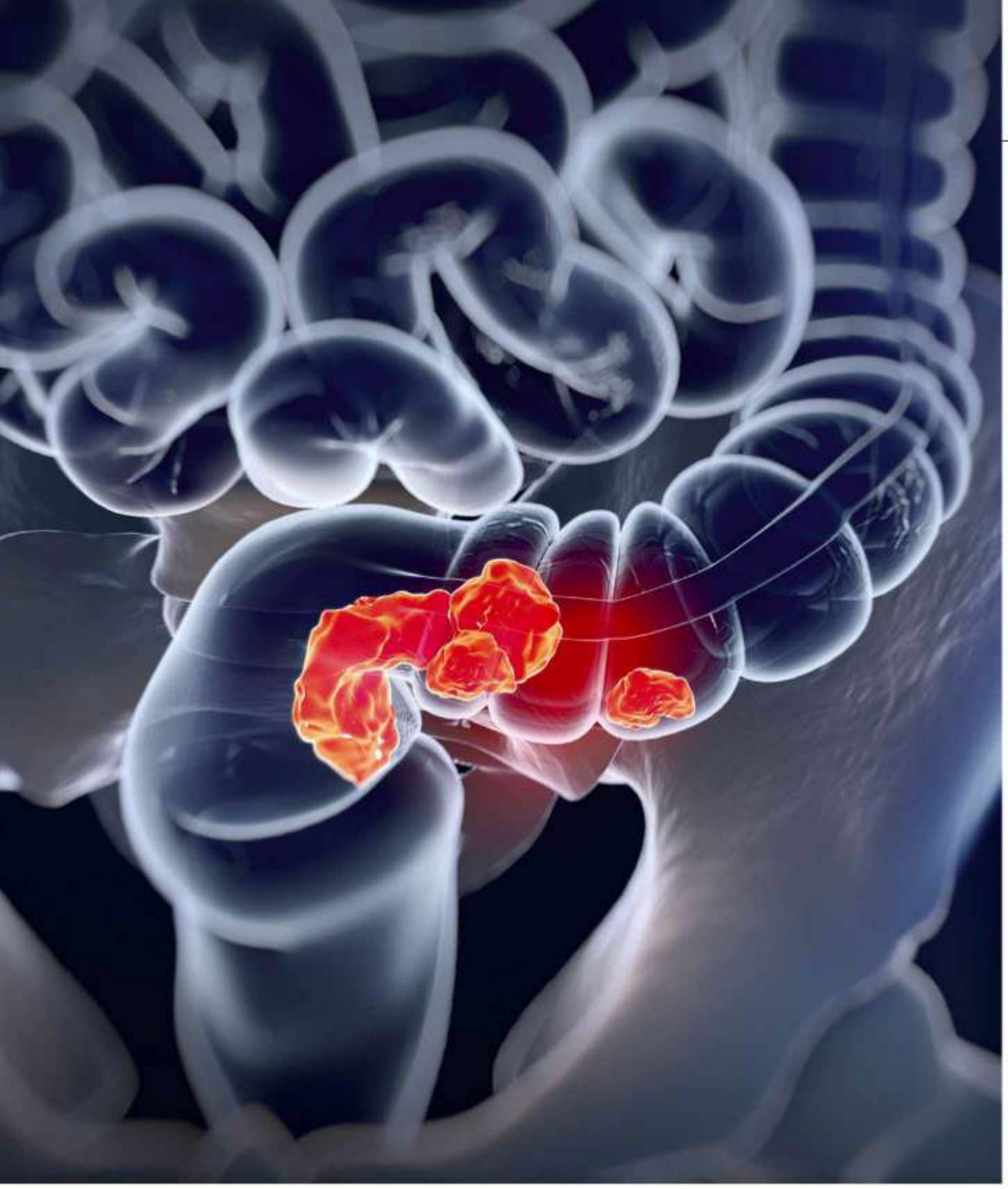
The researchers believe that the evolution of this unusual skeletal structure was driven by headbutting courtship competitions. This means it was likely to also be true for the evolution of the unique neck and head anatomy seen in modern giraffes, they say.

"Both living giraffes and *Discokeryx xiezhi* belong to the Giraffoidea, a superfamily. Although their skull and neck morphologies differ greatly, both are associated with male courtship struggles and both have evolved in an extreme direction," said the study's first author Dr Wang Shiqi.

The researchers believe that during the emergence of the genus *Giraffa* seven million years ago, the direct ancestors of modern giraffes developed a way of fighting by swinging their necks and heads into one another.

Along with sexual selection, this behaviour led to the extreme elongation seen in modern giraffes over the following two million years. This would also have made them particularly well-suited for the niche of feeding on high foliage as a consequence, the researchers say.

WANG YU/GUO XIAOCONG, DR SHIQI WANG, GETTY IMAGES



MEDICINE

DRUG CURES 100 PER CENT OF COLORECTAL CANCER PATIENTS IN SMALL INITIAL TRIAL

Everyone treated remained cancer-free for up to two years, without the need for surgery or chemotherapy

A drug trial carried out in the US may hold new hope for treating cancer. Although conducted on a small number of patients, all of them were found to be entirely cancer free after a course of drug treatment.

The drugs in question are called PD-1 blockers, which inhibit the activity of a protein called PD-1 found on T-cells – the white blood cells that fight antigens. PD-1 and another protein called PD-L1 prevent T-cells from attacking cancer cells, but restricting PD-1 cells' activity leaves the T-cells free to fight the tumour.

Colorectal cancer, visualised here as a red mass in the colon, is the fourth most common cancer in the UK

A team of researchers at the Memorial Sloan Kettering Cancer Center in New York used a PD-1-blocking drug called dostarlimab to treat 14 patients with 'mismatch repair-deficient' (MMrD) stage two or stage three rectal cancers. The patients were given a dose of the drug every three weeks for six months, with a view to continuing treatment with chemoradiation and surgery afterwards, if required.

The researchers found, however, that no such further treatment was needed. Up to two years down the line, all 14 patients are still tumour-free. This offers hope that dostarlimab (or similar drugs) could help to reduce the number of colorectal cancer patients that require surgery each year.

"Two years down the line, all 14 patients are still completely tumour-free"

"Surgery and radiation have permanent effects on fertility, sexual health, bowel and bladder function. The implications for quality of life are substantial, especially in those where standard treatment would impact childbearing potential," said Dr Andrea Cercek, who co-led the research with Dr Luis Diaz, Jr. "As the incidence of rectal cancer is rising in young adults, this approach can have a major impact."

Each year, over 40,000 people in the UK are diagnosed with colorectal cancer. It affects 1 in 15 men and 1 in 18 women, according to the charity Bowel Cancer UK, making it the fourth most common form of cancer in Britain – and the second biggest killer.

Colorectal cancers can take many forms, but around 5 to 10 per cent of them can be characterised as MMrD. This means there have been mutations in genes that are involved in ensuring the successful duplication of other genes, with the result that MMrD cells tend to feature mutations that can lead to cancer. If cancer does arise, MMrD tumours are generally less responsive to chemotherapy and radiation than other forms, leaving invasive surgery as the only treatment. In recent years, however, there has been some significant progress in the use of immunotherapy drugs to treat types of MMrD tumour in different parts of the body.

Writing in the *New England Journal Of Medicine*, another cancer researcher, Dr Hanna K Sanoff from the UNC Lineberger Comprehensive Cancer Center, welcomed the latest findings, saying that they were "very encouraging", but also pointing out that they "need to be viewed with caution until the results can be replicated in a larger and more diverse population".

FLORIDA, USA

SPACE

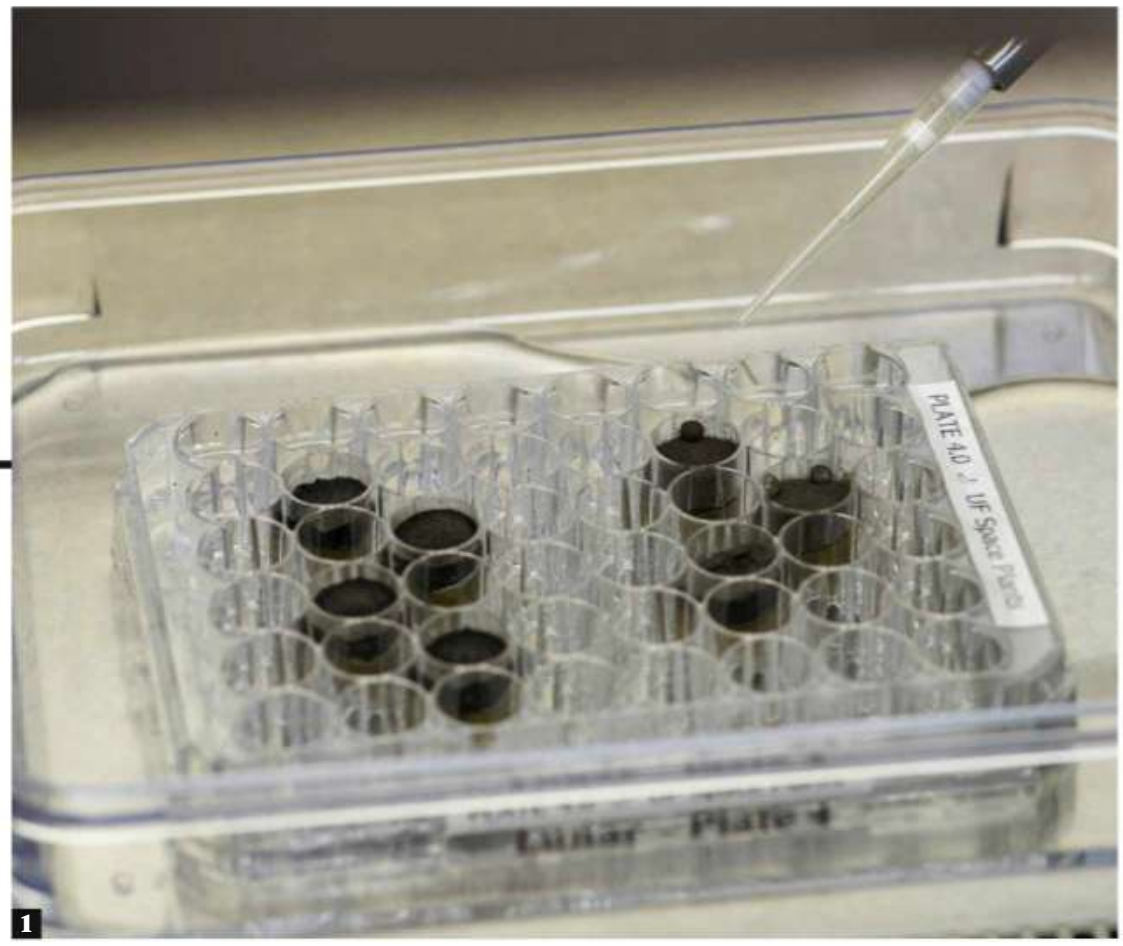
NASA RESEARCHERS GROW PLANTS IN LUNAR SOIL COLLECTED DURING THE APOLLO MISSIONS

If humans want to spend extended periods on the Moon, or travel deeper into the Solar System, we're going to need a reliable food source. Researchers at the University of Florida have found a possible solution to that problem. They've grown *Arabidopsis thaliana* – a green-leafed, cress-like plant in 50-year-old samples of regolith – lunar surface material – that were collected during the Apollo 11, 12 and 17 missions.

They placed the seeds in samples of regolith, put them under LED grow lamps (along with control seeds planted in regular Earth soil and volcanic ash) and fed them with a nutrient solution every day.

"After two days, they started to sprout," said lead researcher Prof Anna-Lisa Paul. "Everything sprouted. I can't tell you how astonished we were!"

After day six, the growth of the samples planted in the regolith began to slow and when later examined were found to have stunted roots and leaves. The plants' growth also varied according to which mission's regolith they were planted in, with the Apollo 11 samples faring worse than the others. It's hoped that further research will lead to plants that can be made robust enough to thrive in lunar surface material.



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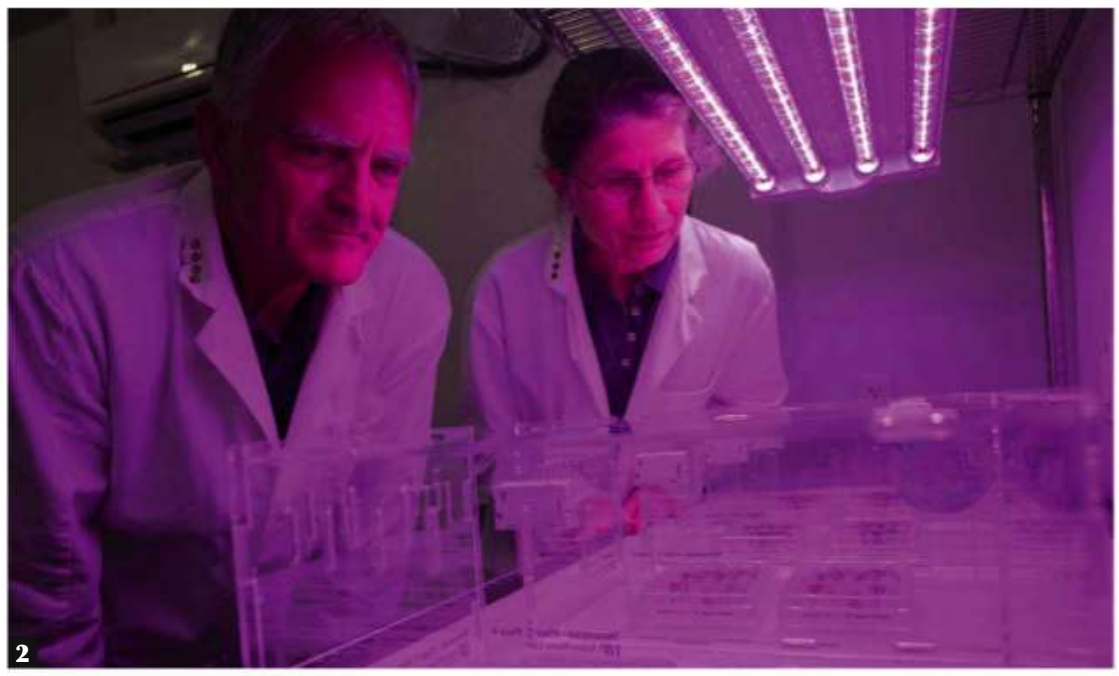
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3

1. Lunar regolith is hydrophobic – meaning it repels water – so the researchers needed to mix water through it before planting the seeds.

2. Profs Rob Ferl and Anna-Lisa Paul monitor the seeds growing in the soil samples underneath the LED grow lamps.

3. The plants will now undergo genetic analysis to identify any alterations that could be made to their DNA to help them grow more easily in the regolith.

4. After 16 days, the plants grown in the lunar regolith (top of the photo) are visibly less developed.

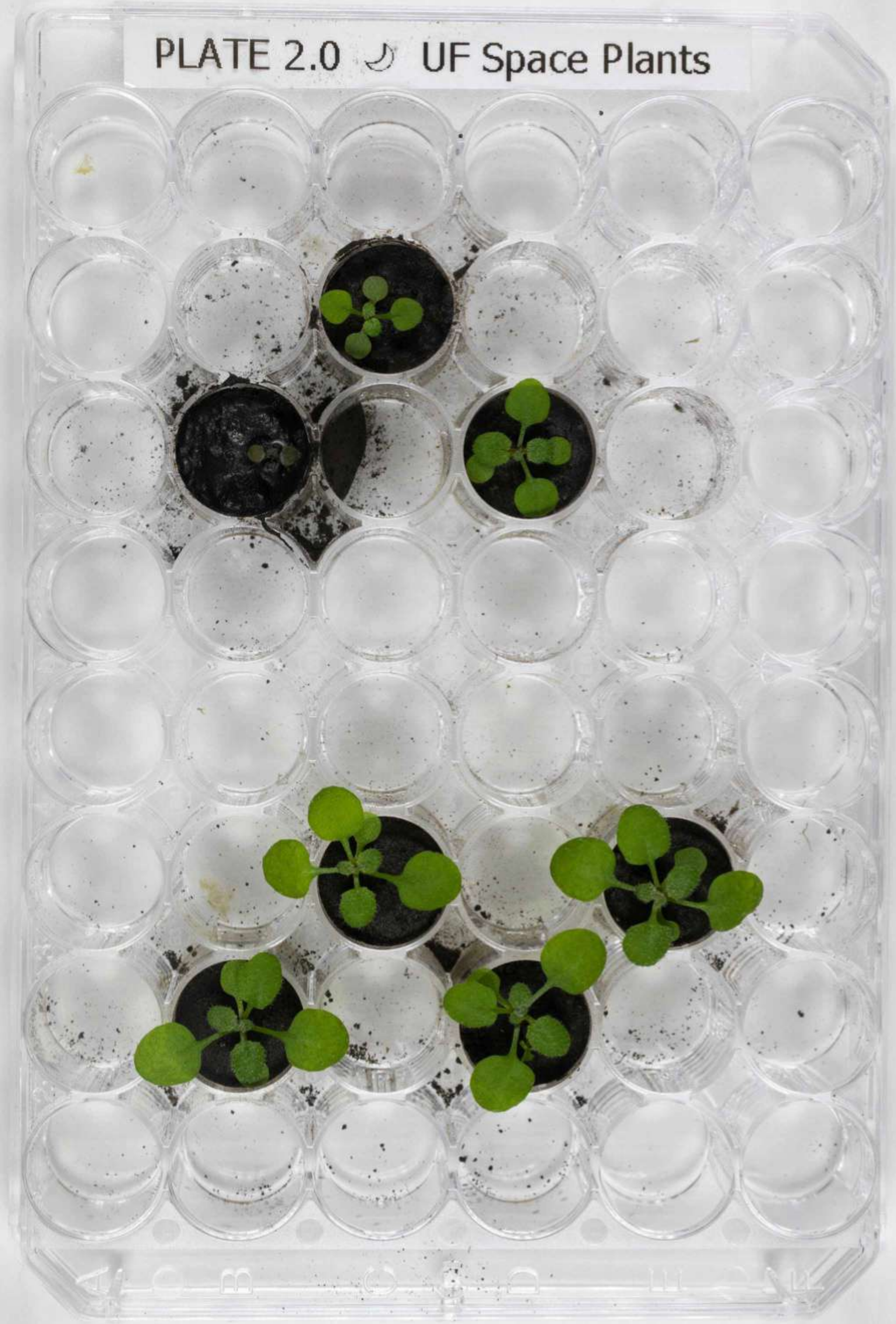


PLATE 2.0
UF Space Plants

HORIZONS

ANIMAL BEHAVIOUR

SEARCH AND RESCUE RATS ARE BEING TRAINED TO FIND EARTHQUAKE SURVIVORS AMONG THE RUBBLE

Researchers have successfully trained rats to detect landmines, sniff out tuberculosis and even drive cars, but their next challenge – to find survivors in collapsed buildings – could be their bravest yet

APOPO X2

WHY RATS?

They can contribute something that the other technologies can't, at least for the areas we work in. Their sense of smell and their trainability is on a par with dogs. But it's the rats' small size that really makes a difference.

At APOPO [an acronym from the Dutch for Anti-Personnel Landmine Detection Product Development], we work with the African giant pouched rat (*Cricetomys ansorgei*). We taught them to detect landmines because they're too small and too light to trigger the devices. We're teaching them to detect the scent of illegally smuggled wildlife in shipping ports because they can reach the containers stacked up high on top one another.

For my research in training rats for search and rescue, the main reason is that they can get into the small, tight areas of a debris site. Search and rescue dogs typically just go around debris sites, whereas we're hoping the rats can actually go inside, through all the rubble, because they're so small.

Any application of them has to be in response to a humanitarian challenge, and it has to require the unique capabilities of our rats to help. If there's already [other] effective technology available, and it's affordable, we're not going to train our rats just for the fun of it.

HOW DO YOU TRAIN A RAT TO SEEK OUT BURIED SURVIVORS?

We use positive reinforcement to train them on a basic sequence of behaviour. So, here it's to search for a human, indicate to us that they've found them, and then return to where they were released.

[Training] starts off in a really basic environment: a small, empty room. Then we gradually expand and increase the complexity so it becomes more like real life. We can start adding in debris and making the training area look more like an actual collapsed building site.

WHAT HAPPENS WHEN ONE OF THE RATS FINDS A SURVIVOR?

They need to trigger a switch that makes a noise. Currently, we get them to wear a vest that has a little ball on its collar, a ball containing a microswitch. The rats are trained to pull the ball when they find someone, which triggers the microswitch and lets out a beep.

Pulling the ball isn't a natural behaviour for them, but they can be trained through a process we call 'shaping'. We start by putting the vest with the ball on the rats. They're naturally quite curious, so when they have the ball hanging there, you can see they're kind of like, 'What is this?'

In the beginning, we're just reinforcing them for touching the ball at all. Then, as is standard for shaping, you would stop reinforcing for just touching so they realise, 'Oh, I'm not getting reinforced any more'. Then they'll try harder [to get the reward]. That typically leads them to pull on the ball and, when they do, we have to really quickly reward them, so they know that's the target behaviour. Then, in a similar way, we can continue shaping until they're pulling it for two to three seconds, so it's a really strong signal to us.

Of course, in the field we won't be able to see the rats, or hear them.

The search and rescue rats are trained in rooms that are gradually filled with debris to increasingly resemble the site of an earthquake

“For these projects it costs, on average, around €6,000 to fully train one rat so they’re ready for operations”

So, we’re working with a group of engineers to develop a multi-function backpack that’s linked up to our computer so that we’ll be notified when the rats pull the ball. We’ll be able to know exactly where they are, because the backpacks should have a location transmitter, as well.

HOW CAN THEY TELL THE DIFFERENCE BETWEEN THOSE WHO ARE ALIVE AND THOSE WHO AREN’T?

We’ve talked about this a lot, because we’ll only do the training with living people. However, dog trainers have told us that the odour profile of a person that’s alive, compared to a person that’s dead, is very different. Dogs can tell the difference between a living and deceased person from around three to four hours after death.

We thought that maybe we’d have to train the rats using some sort of smell that we might be able to get our hands on – it’s hard to know what to call it, but, basically, we would need the smell of death.

But the dog trainers have told us we don’t have to do that, because the odour change between living and dead people is so different that it’s not a problem.

WHEN WILL THESE RATS BE PUT TO WORK IN THE FIELD?

We just started training in August 2021 and we still have to run training trials outside the research environment. We’re working with a search and rescue group called GEA, who are based in Turkey, a country that’s prone to earthquakes. We’re hoping that by next year we’ll be able to take the rats to Turkey for trials there, but in terms of going to real disaster sites – real collapsed buildings – it’s very difficult to tell.

APOPO’s landmine research started in 1998, and its first operational trials were in 2003/4. Our tuberculosis detection research began in 2003, and the rats began operating in 2007. For these projects it costs, on average, around €6,000 [approximately £5,175] to fully train one rat so they’re ready for operations.

We’re currently training seven for search and rescue, although they have to take turns using the backpack – we’ve only got one at the moment!

DR DONNA KEAN
Donna is a behavioural researcher at APOPO, training rats to search for and rescue earthquake survivors.

THE FUTURE'S BRIGHT...

As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From resilient corals to lab-grown meat, here you'll find many reasons to feel hopeful for our future...

A dog breeder in the Netherlands is working to improve the health of French Bulldogs, a breed known for its short muzzle and breathing difficulties. Hawbucks Franse Bulldog Kennel hopes that by selectively breeding for wider nostrils and a longer nose, they'll slowly be able to give their dogs a better life.

Bristol City Council is now offering a licensed drug testing service, to check the chemical make-up of substances being used in the community and offer personalised healthcare to those in need. The hope is that offering a confidential and accessible service will reduce high-risk drug-taking in the long term.

YEARS TO GO

25

Pink sea fan coral is more resilient than once thought. The soft coral is currently found across southwest Britain, the Channel Islands and northwest France, and despite rising temperatures, its habitat should remain safe at least for the next 60 years.

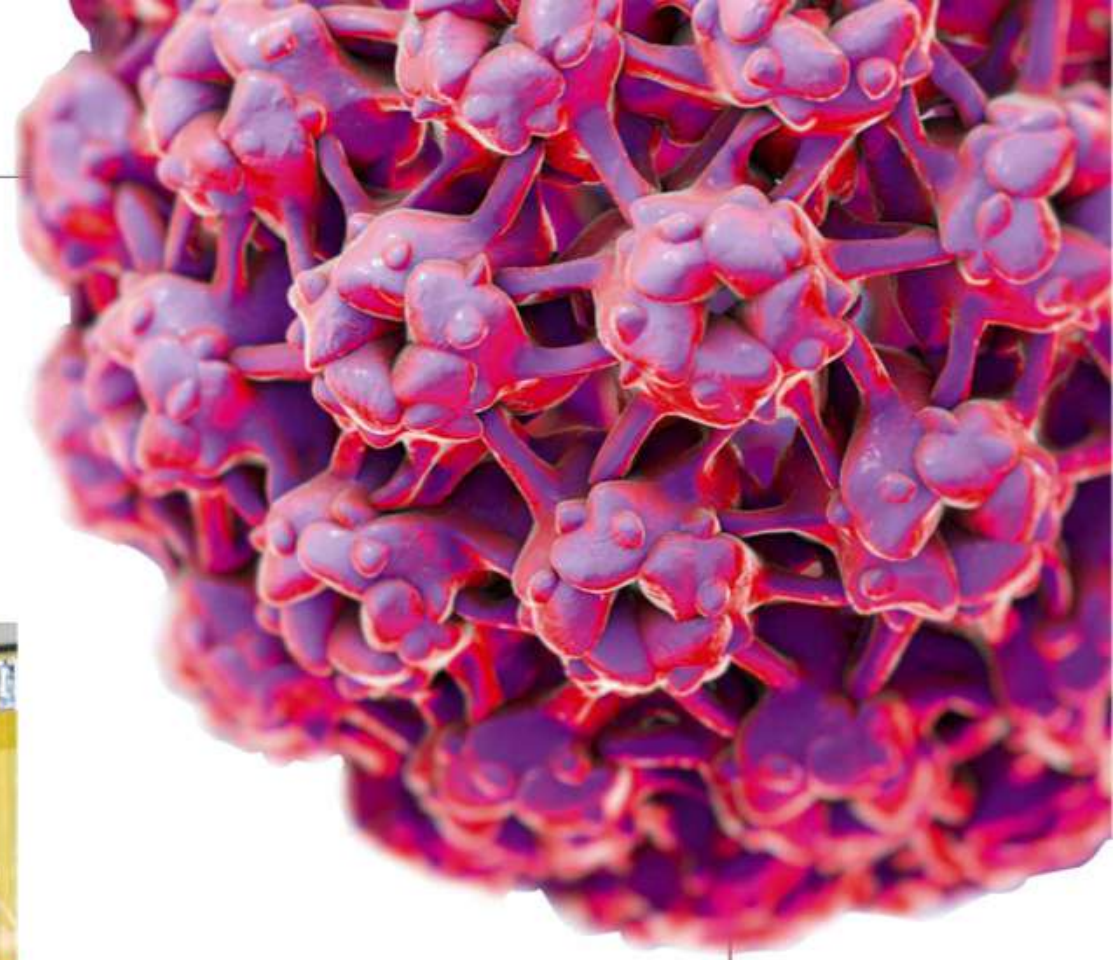
New research into our ageing bodies has uncovered changes to blood cells that happen when we hit 70 years of age. Further understanding of these cell mutations could help us minimise disease in an ageing population.

A study on obese mice has shown that a high dose of a molecule named Lac-Phe, which is naturally produced in humans during exercise, can halve their food intake. Researchers hope it could one day lead to a pill for people struggling to lose weight.

20

Scientists have developed a way to grow cow muscle cells using nutrients taken from plants. The growth medium, called 'Beefy-9', is much cheaper than the technology currently used to produce lab-grown meat, bringing no-kill steaks one step closer to our shelves.

ALAMY/PA, GETTY IMAGES X7, TYLER GUARINO, GABRIELLA BOCCHETTI/ UNIVERSITY OF CAMBRIDGE, KELSEY SIMPKINS/UC BOULDER

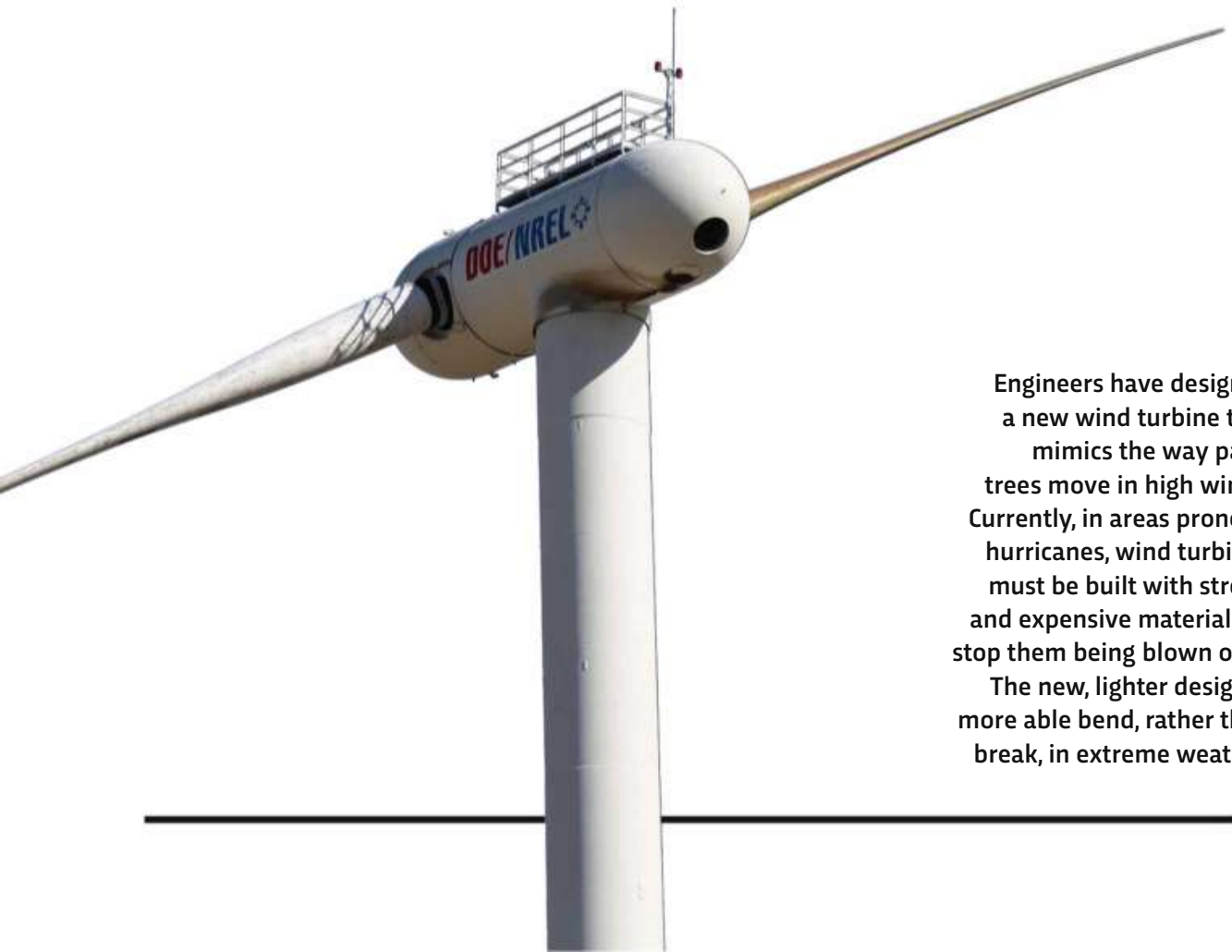


A new supercapacitor – a battery-like device that stores energy – can absorb carbon dioxide from the atmosphere as it charges. The CO_2 then dissolves into a solution similar to seawater in the supercapacitor. The tech is a long way off being scaled up for use, though.

As lab tests have improved, women now only need to have pap smears every five years, instead of three.

10

Engineering students at Johns Hopkins University have solved an age-old problem – stopping a burrito from falling open right before you take a bite. The edible 'Tastee Tape' keeps the fillings inside the flour tortilla, and is even vegan and gluten-free. Maybe one day you'll be able to buy a roll of the tape from your local supermarket.



Engineers have designed a new wind turbine that mimics the way palm trees move in high winds. Currently, in areas prone to hurricanes, wind turbines must be built with strong and expensive materials to stop them being blown over. The new, lighter design is more able bend, rather than break, in extreme weather.

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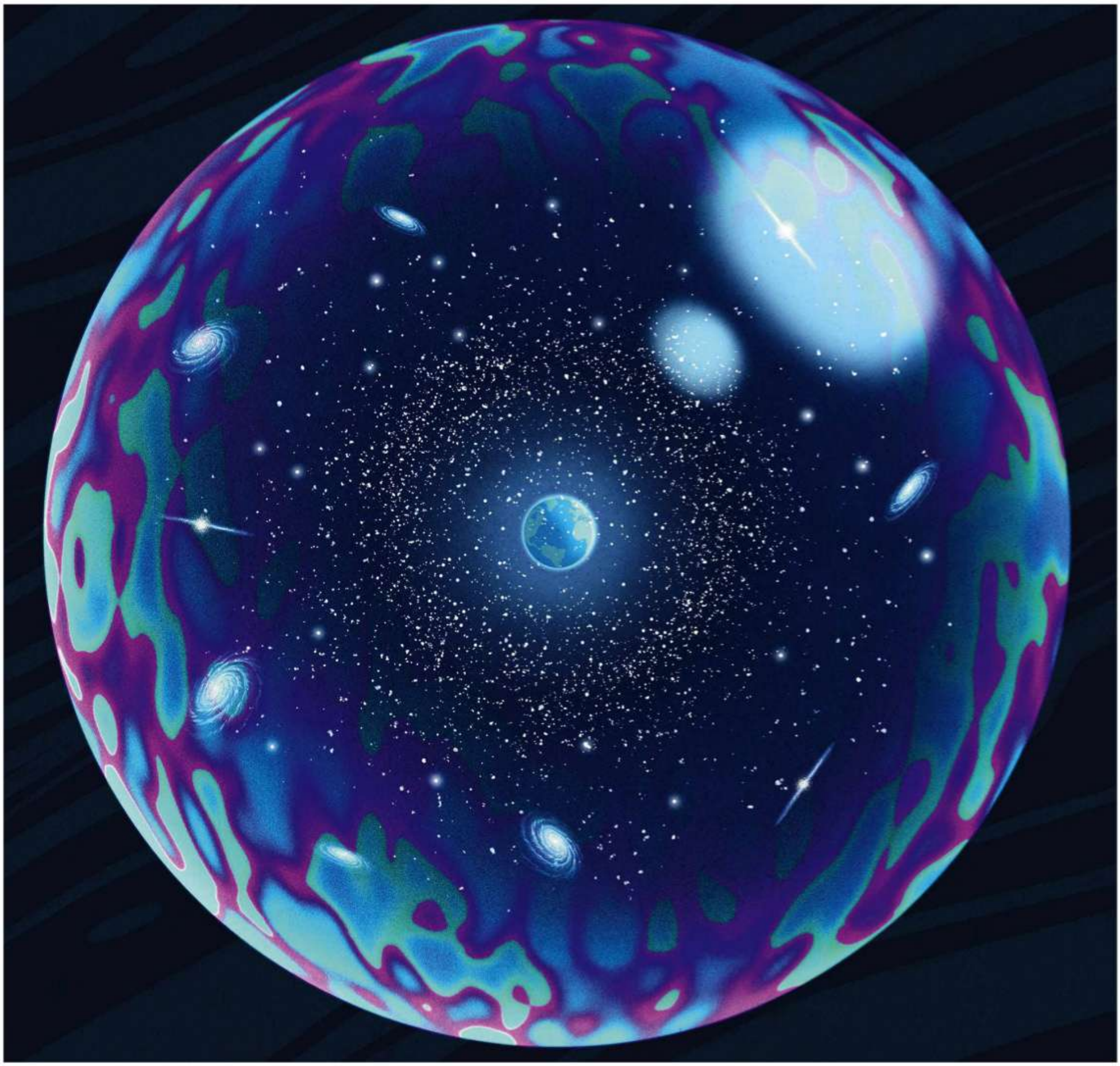
A man whose hands were left permanently closed in the fist position has undergone a successful double hand transplant at Leeds General Infirmary. Steven Gallagher has scleroderma, a condition that affects the skin and internal organs, and is the first patient with the condition ever to receive the surgery.



COMMENT

AT THE EDGE OF EVERYTHING

Puzzling over the answers to a centuries-old cosmic paradox can teach us profound things about the Universe

Whether it's more troubling to imagine that the Universe goes on forever in every direction, or that it has an edge, beyond which there is nothing, is hard to say. Astrophysics doesn't provide any guidance as to which flavour of existential crisis we should be having – while we can't say with any level of confidence whether the Universe goes on forever or not, we can say that our observable universe has an edge, in the sense that

there's a distance beyond which, whatever may or may not exist, we absolutely cannot see it.

The existence of this cosmic horizon is part of the answer to an ancient conundrum about the darkness of the night sky, reportedly first posed by Johannes Kepler in 1610 but later attributed to fellow astronomer Heinrich Olbers in the 1800s.

Olbers' Paradox asks: if the Universe is infinite, and if there are stars (or galaxies) throughout it, why is the sky dark? Surely, if we look in any direction in the sky, that sightline will, eventually, land on a star. Common sense therefore tells us that everywhere we look, the sky should be as bright as the Sun, constantly aglow.

"Surely, if we look in any direction in the sky, that sightline will, eventually, land on a star. Common sense therefore tells us that everywhere we look, the sky should be as bright as the Sun, constantly aglow"

SOLVING THE PARADOX

The standard resolution to this paradox invokes the finite age of the cosmos and the speed of light. Even if the cosmos is endless and full of stars, one might reason, we can only see the ones that are close enough for there to have been enough time (since the beginning of the Universe) for the light to reach us from there. Anything so distant from Earth that the light travel time is more than the age of the Universe is invisible to us.

This doesn't entirely resolve the paradox, for reasons that involve some much stranger physics. But this light travel distance limit is responsible for our horizon – the edge of the observable universe. The most distant things we can see in the cosmos are the things whose light has been travelling to us for the age of the Universe: 13.8 billion years.

The stranger physics comes in when you ask what are those things whose light has travelled for that long? The Big Bang theory says that the Universe 13.8 billion years ago was a hot, dense inferno, in which all of space was filled with glowing-hot plasma, rippling and churning like the surface of the Sun. Because all of space was glowing, when we look into the farthest reaches of the cosmos in any direction, that glow is in fact what we see.

So if all of space was glowing, why is the sky dark? Have we just unsolved the paradox?

The reason the Universe can be glowing all around us but still look dark comes down to the physics of light in an expanding universe. When space expands, and the distance between objects grows, the light passing between those things gets stretched out, shifting the light to lower frequencies on the electromagnetic spectrum. For visible light, lower frequencies correspond to redder colours, so this effect is called "redshift". You can think of it like a Doppler shift – the same kind of effect that's responsible for a siren dropping to a lower tone when an ambulance speeds away from you, since distant objects appear to speed away from us as the Universe expands.

But this effect is not limited to visible light: it spans the whole spectrum. Visible light gets stretched to infrared, infrared to microwave, microwave to radio. And the farther away that light, the more the cosmos has expanded, and hence the more intense the redshift. Light from the glowing early Universe has been so stretched out by cosmic expansion that we now receive it as a faint glow of microwave radiation, all around us.

While we may never know if the Universe as a whole is infinite or bounded, we know that the cosmic microwave background – the distant shell of fading fire that surrounds us – is the most distant light we can ever see, at the edge of our observable universe. But just like the darkness of the night sky, this edge is a matter of perspective. Someone living in a galaxy billions of light years away from us sits at the centre of their own observable universe, which may only partly overlap our own.

There will always be mysteries that the fundamental laws of the Universe will not allow us to unlock. But whether we blithely accept our limitations or not, the best approach to understanding will always be in learning to look around us in new ways, and question why it is that we see what we see. Or why we might look up on a particularly dark night and not see anything at all.

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

NERISSA ESCANLAR ILLUSTRATION: MYRIAM WARES

COMMENT

MEMORIES ARE OUR OWN TRUTHS... TRUTHS THAT CAN LIE

False memories make for thorny debates in research and the courtroom alike

DR JULIA SHAW
(@drjuliashaw)
Julia is a psychological scientist at University College London, the author of multiple best-selling books, and the co-host of the hit podcast Bad People *on BBC Sounds.*

False memories ignite people's imaginations, particularly when they crop up in high-profile court cases. Such as in 2021, when socialite Ghislaine Maxwell was accused – and convicted – of child sex trafficking.

During the trial, the defence called the most eminent researcher in the field of false memory, Prof Elizabeth Loftus of the University of California Irvine, to the stand. There, she said something that memory researchers say on a regular basis: "[Memory] doesn't work like a recording device… We are actually constructing our memories while we retrieve memories." But a statement that in a university lecture hall would simply be taken as a scientific fact, is often decried as unethical during a trial. Why is it that, in the courtroom, experts like Loftus often come under attack, accused of undermining witnesses?

False memory is the term given to recollections that are either partially or completely incorrect. We all have memories that are flecked with false details: memories where we get our own ages wrong, or remember a friend coming to an event they didn't actually attend. It's even quite common to 'steal' entire memories, particularly from siblings.

In criminal justice settings, the same processes can involve a witness misidentifying a perpetrator or misremembering important details – even an entire crime. False memories are not deliberate lies, but unintentional subjective realities. False memories are our own truths.

But where do false memories come from? In 2015, I ran an experiment to find out. After three leading or suggestive interviews 70 per cent of my participants developed false memories. Many confessed, in vivid detail, to crimes that never actually happened. Further studies showed that these false memories seemed real to others. Of course, research like this must go through ethics boards, and participants were debriefed. But these studies showed how false memories could be created and whether they can be reliably differentiated from true memories. They might help us prevent false memories from arising in real-world situations where the stakes are much higher.

In a legal setting, false memory experts are typically called to work on cases where elements of an important memory are thought to be false.

ILLUSTRATION: SCOTT BALMER

“Memory researchers have long accepted that false memories exist, even in normal brains”

Maybe CCTV footage doesn’t match an eyewitness’s account, or someone asked to identify a suspect goes from being unsure to very confident. The question for the expert witness is whether these mistakes could be due to false memories. Educating police, jurors and judges on how memory works should enable them to better differentiate between high- and low-quality (or even impossible) memory evidence.

Although I have been hired by the prosecution, as an expert I have most often been hired by the defence. This is because of how the burden of proof works. The defendant’s lawyers want to introduce reasonable doubt, and calling into question how witnesses remember events is one way to do that.

Within memory research, there are also heated debates. Who is to say what counts as a false memory? I have argued that only individuals themselves can know if a memory feels real to them, but other memory experts think that only researchers can spot a false memory. Such arguments have led to instances where false memory experts hired by the defence and the prosecution end up battling out their scientific disagreements in court, making it all seem more confusing than it really is. Memory researchers as a whole have long accepted that false memories exist, even in normal brains.

But in cases where memories are the primary evidence, including in cases involving sexual assault where there is no physical or CCTV evidence, the stakes are high and emotions even higher. Researchers like Prof Loftus and myself move between two worlds: the scientific world, where facts triumph, and the judicial world, where ‘legal truths’ triumph and the only thing that matters is what can be proven in court.

Why do we bother? Most of us became interested in false memories because of cases of wrongful conviction. It makes a lasting impression to see a victim point with certainty at a suspect, only to realise years later that the person they helped imprison was not the perpetrator at all. As false memory experts, our job is to help prevent unreliable evidence from contaminating the justice system, one tiny courtroom lecture at a time.

BBC SOUNDS

Listen to Dr Julia Shaw on the *Bad People* podcast, available on BBC Sounds.

COMMENT

THE ROBOTS ARE COMING FOR YOUR JOB... IF YOU'RE A DOLPHIN

The use of performing animals in circuses and aquariums is controversial. Could realistic, animatronic creatures offer a way to ignite people's interest in the natural world instead?

This year, in March, I jumped into a heated pool in California to meet a dolphin named Delle. As I approached her, I was captivated by the smooth movements of the powerful, 250kg body gliding through the water. After swimming a few laps, Delle turned towards me and became playful, greeting me by splashing me with her beak. Delighted, I reached out to stroke her shiny skin. It felt rubbery, which, along with the thin cable snaking along the bottom of the pool, was the main giveaway that Delle the dolphin was a robot.

Delle, a hyper-realistic animatronic dolphin, was created with the goal of replacing real dolphins in aquariums and marine amusement parks. While some might lament the showcasing of replicas instead of live creatures, the idea has merit.

"People tend to treat interactive robots like they're alive, even though they know perfectly well they're just machines"

DR KATE DARLING
(@grok_)
Kate is a researcher at MIT, where she investigates technology and society, and studies human-robot interaction.

Captive animals have long been a source of human entertainment. We've kept lions in cages for thousands of years, enraptured medieval towns with travelling circuses, and opened the first modern zoo in Paris in 1793. More recently, animals became both props and protagonists on the silver screen. In fact, the company behind Delle the Dolphin, named Edge Innovations, was a big player in the world of special effects, creating mock sea animals for Hollywood films like *Star Trek*, *Free Willy*, and *The Perfect Storm*. One of the benefits, aside from adding to filmmakers' entertainment tools, is that it's easy to assure viewers that 'no animals were harmed'.

Just as fake animals are becoming deceptively realistic, it's becoming increasingly less acceptable to use live animals for entertainment purposes. Documentaries like *Blackfish* (2013) and *The Cove* (2009) have exposed some of the horrific treatment and suffering of ocean mammals. The resulting public outcry has rendered marine parks controversial, attracting more protesters and less visitors. It's not just aquatic animals: countries around the world have begun to ban circus animals. The iconic Ringling Bros. and Barnum & Bailey Circus featured performing elephants, tigers, and other attractions for over a century before animal cruelty protests drove them out of business in 2017. They recently announced a comeback – without the live animals.

And yet, arguably, entertaining people with captive animals is vital for animal conservation. Many zoos and aquariums actively try to promote conservation efforts by providing educational experiences and encouraging interest in the natural world. Giving kids (and grown-ups) the opportunity to see and interact with live animals is generally a lot more exciting and engaging than something in a book or on a screen. This type of entertainment is useful, because it inspires people to care. And even staunch animal rights activists are divided on the costs and benefits of zoos, since they recognise the value in getting newer generations interested in the animals' lives.

At first, this seems like a reason to avoid replacing the animals with technology. And yet, research in the burgeoning field of human-robot interaction is showing astonishing results on engagement with robots that can mimic lifelike behaviour. When physically embodied and interactive, robots attract a lot of attention. People tend to treat them like they're alive, even though they know perfectly well they're just machines. To paraphrase the research: we're suckers for things that look cool and move.

Take Delle the dolphin. The current version of this device isn't so much a robot as an animatronic, meaning it has no autonomous behaviour. The dolphin's body is entirely remote-controlled. But for the engagement effect, it barely matters whether Delle is an animal, a robot, or a mechanical puppet. According to Edge Innovations, you can tell the people who interact with the dolphin exactly what's going on and they don't care. They are just excited to play with it.

If we start to replace the animals in our theme parks with machines, will this trend decrease our wonder for the natural world? A bunch of people expressed negative gut reactions after I posted footage of the robot dolphin on Twitter. And yet, I don't believe that using this robot replica will cause us to forget the worth of living creatures. My personal experience matched the Delle creators' claims: swimming with a doppelgänger was thrilling, and even more fun knowing that no animals were harmed in the process. If anything, I came away from the experience reminded of how precious real dolphins are.

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Pathological liars | Monkeypox | Climate change

REVIEW

PATHOLOGICAL LIARS: WHAT DRIVES THEM TO LIE AND WHAT CAN YOU DO ABOUT IT?

From high-profile court cases to recent political scandals, lying is all over the news. A psychologist explains how to spot and deal with a habitual liar

"While psychopaths and people with an antisocial personality are typically manipulative and self-serving, pathological liars often lie for no apparent purpose"

BBC *Visit the BBC's* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

The label 'pathological liar' gets thrown around a lot, especially in the direction of politicians or celebrities. Although it isn't a formal psychiatric diagnosis, it is a recognised concept that psychologists and psychiatrists have been interested in for a long time, at least since 1891 when the German psychiatrist Anton Delbrueck coined the label *Pseudologia fantastica* to describe several of his patients who told an astonishing amount of fantastical lies (other similar psychological terms include 'deception syndrome' and 'mythomania'). So why do people do it?

HOW CAN YOU SPOT A PATHOLOGICAL LIAR?

While psychopaths and people with antisocial personality disorder can be inclined to excessive lying, most pathological liars are not psychopaths, nor do they necessarily have a personality disorder. Indeed, while psychopaths and people with an antisocial personality are typically manipulative and self-serving, pathological liars often lie for no apparent purpose. Another key feature of pathological lying, as opposed to being a common-or-garden compulsive liar, is that the lies are often particularly bizarre or far-fetched.

Consider the results of a recent survey carried out by two US psychologists – Dr Drew Curtis and Dr Christian Hart – who believe pathological lying should become a discrete psychiatric diagnosis. The pair asked hundreds of volunteers to complete several measures of lying behaviour and found that between 8 per cent and 13 per cent of them met the criteria for being a pathological liar.

WHY DO PATHOLOGICAL LIARS TELL FIBS?

The details from the surveys fit in with some theories in scientific literature suggesting that pathological liars tell tall tales – especially of far-fetched past achievements or suffering, or grandiose social connections – as a kind of unconscious strategy to boost their fragile sense of self or low self-esteem.

For instance, in 2007 a team of Canadian psychologists reported the case of 'Lorraine,' whose dramatic lies included a colleague sending her death threats, a friend developing a lesbian infatuation, a supposed death threat from a fiancé's ex-wife, and her fiancé's three-year-old setting fires in relatives' homes. The team, led by Dr Cheryl Birch, said that the pattern was characteristic of pathological lying because the lies were harmful to Lorraine (she actually ended up in a secure forensic unit) and they weren't inspired by any apparent clear motive – they seemed to be driven by a deeper psychological need to present herself as a hero or victim.

In a case reported by a team of New York psychologists in 2015, a woman told her therapists she had made several suicide attempts. She also claimed her mother had been executed in California for killing her father and stepfather, that her brother and sister had been killed and buried in the backyard by her mother, and that she had two children, including one who was the product of a rape by one of her siblings. Subsequent investigations suggested none of this was true, except that

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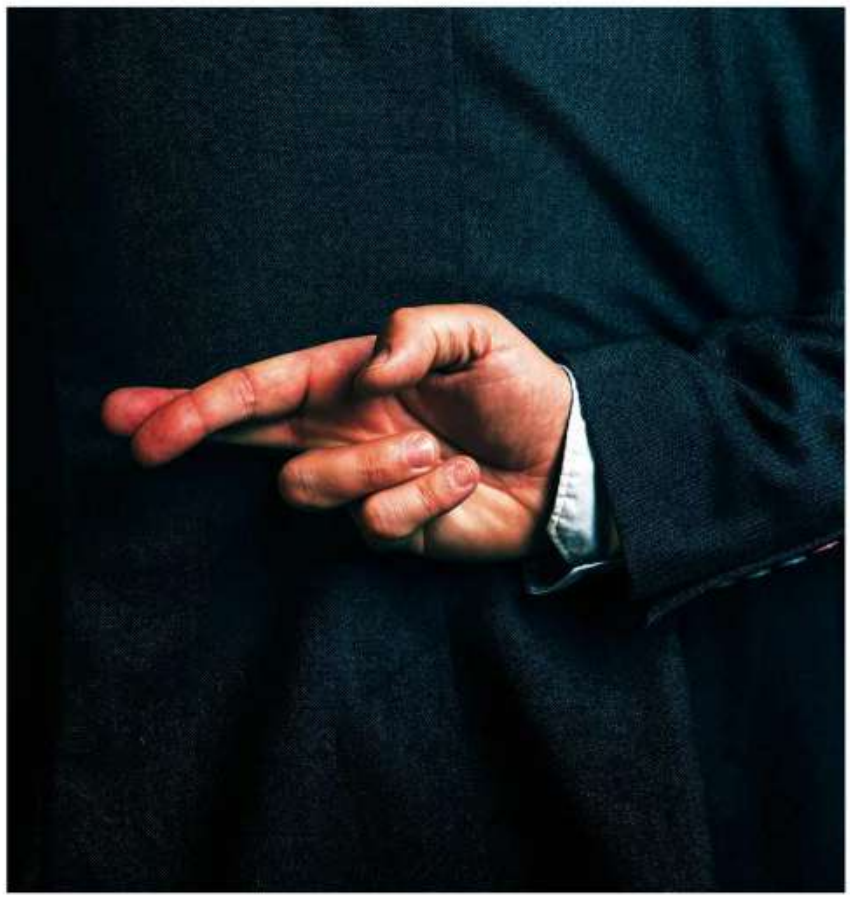


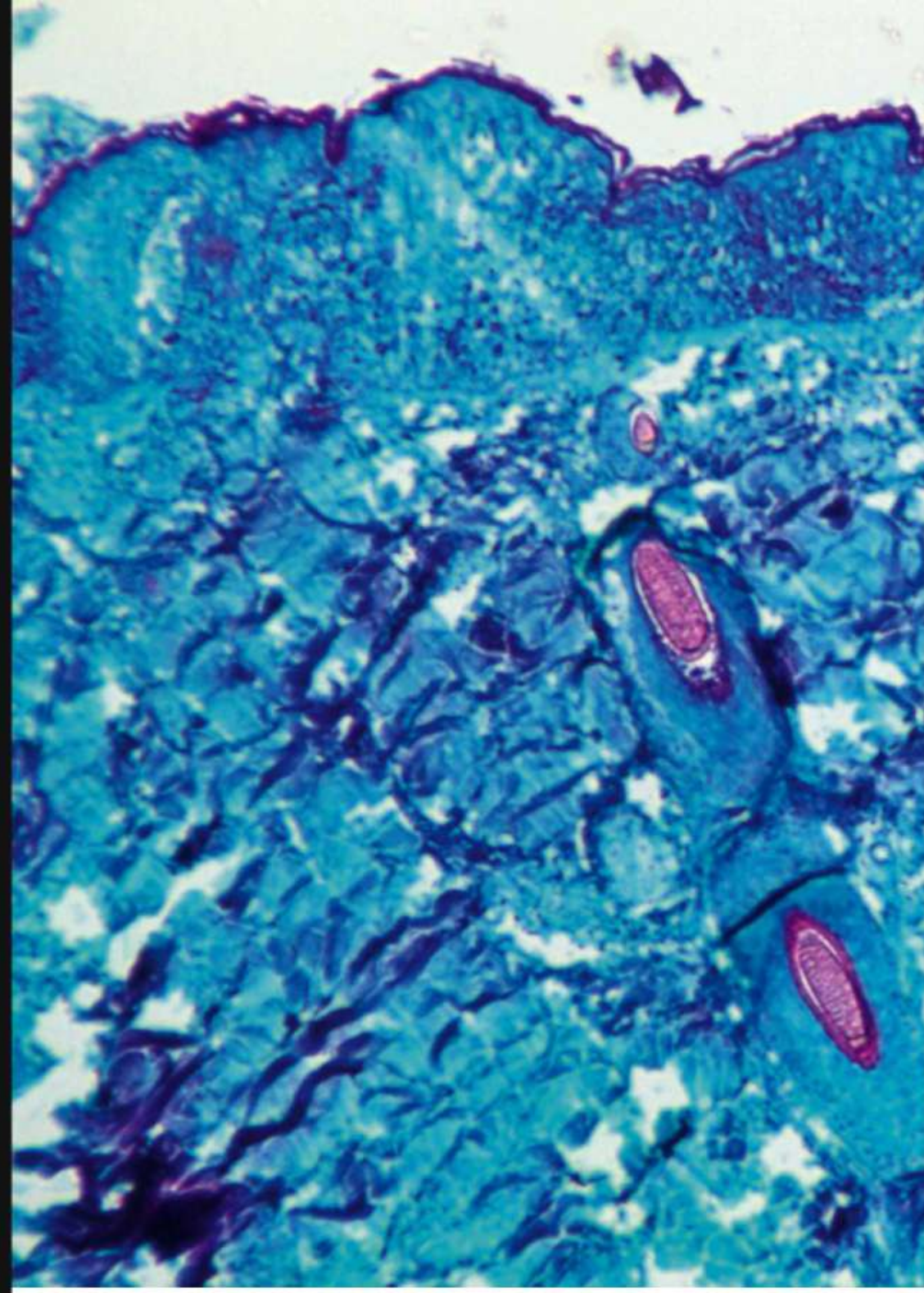
she did have one son. This team, led by Dr Panagiota Korenis at the Bronx Lebanon Hospital Center, agreed with the other experts that habitual or compulsive lying of this kind usually emerges as a "means to assert autonomy in the face of lack of self-esteem".

HOW SHOULD YOU DEAL WITH A PATHOLOGICAL LIAR?

When it comes to coping with a pathological liar, it's perhaps worth remembering the likely cause of the person's tendency to tell so many far-fetched stories. While their behaviour might be irritating and even cause serious harm (especially when it comes to false allegations), if it's driven by a deep-seated insecurity, then you might be wise to see it as a call for help, and to resist the urge to confront the person too forcefully or without sympathy.

If the pathological liar in your life is someone you care about, perhaps you could help them find more productive ways to address their low self-esteem and anxiety, or even to come to terms with a difficult past, if that's relevant. Although research into effective treatments is largely lacking (partly because 'pathological liar' has yet to be recognised as a formal diagnosis), a sensible step could be to gently encourage the pathological liar you know to seek professional mental health support.

by **DR CHRISTIAN JARRETT**
(@Psych_Writer)
Christian is a cognitive neuroscientist and psychology writer. His latest book is Be Who You Want: Unlocking The Science Of Personality Change *(£14.99, Robinson).*

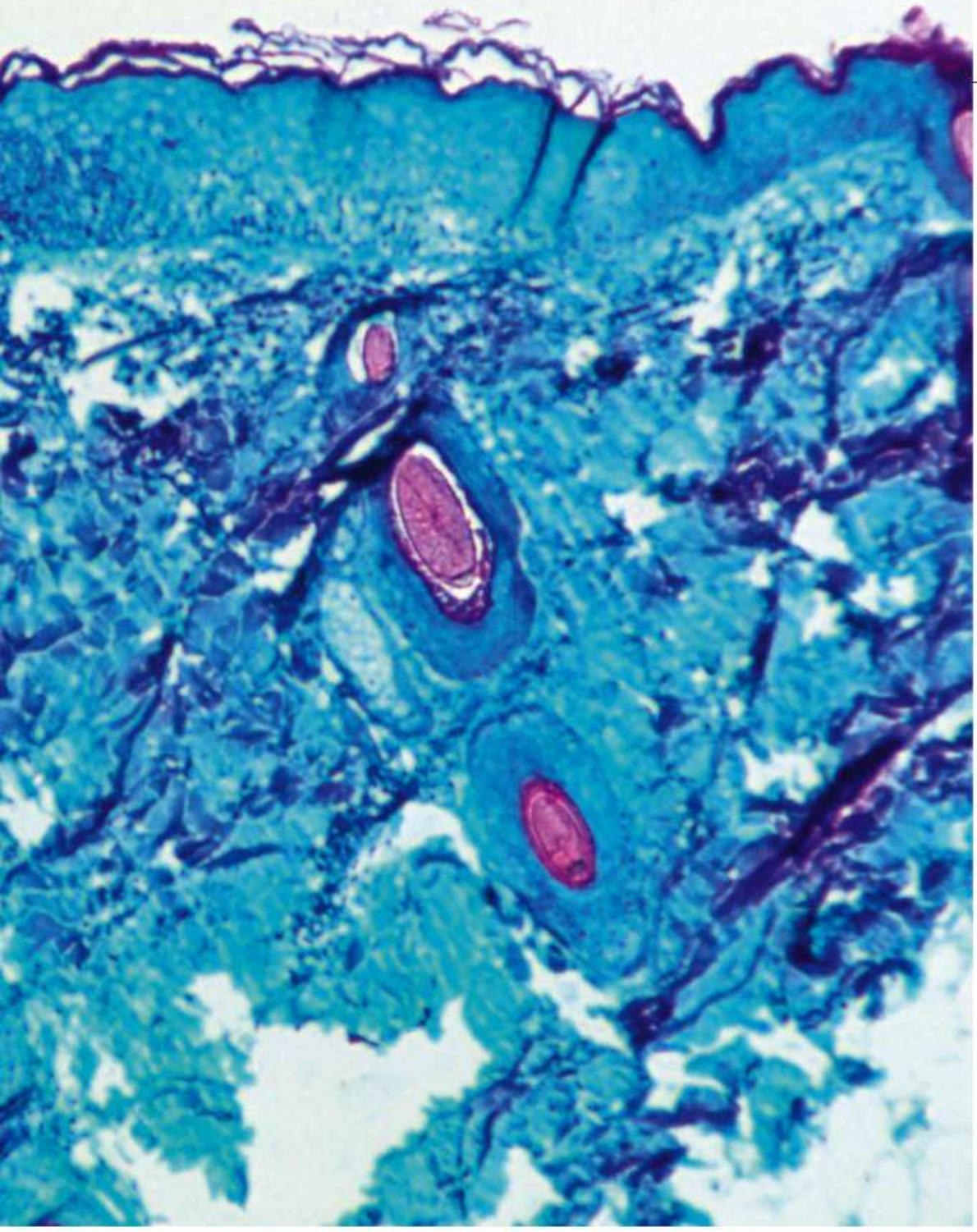


ANALYSIS

MONKEYPOX OUTBREAK: HOW WORRYING IS IT?

This rare disease, mainly found in Africa, is unlikely to become a new pandemic in UK, but cases are going to rise over the coming weeks

Though still in the midst of the current COVID-19 pandemic, we are now seeing warning signs of another disease popping up in countries around the world – monkeypox. This is not a new virus (it was first discovered in 1958), nor is it new to the UK (there have been regular small outbreaks over the years). However, we are now seeing a wider spread of the virus, with 100 cases and nearly 300



ALAMY, CDC/PHIL.GOV

ABOVE The monkeypox virus in the skin of a monkey, as seen under a microscope

suspected cases reported in more than 16 countries, including 57 cases in the UK, as of 24 May. Are we staring down the barrel of another pandemic?

Recent years have seen 13 isolated outbreaks of monkeypox that have been mostly contained to a single country and can be traced back to travel from Central and West Africa, where the virus is thought to reside. In May and June 2021, there were three cases of monkeypox in the UK that were linked to recent travel to West Africa. However, according to the World Health Organization, the current outbreak is proceeding differently, with many more cases, more human-to-human transmission and more people that became infected outside of Africa.

In Central and West Africa, monkeypox typically spreads from infected animals to humans, though some human-to-human transmission does occur. The Centre for Disease Control and Prevention states that monkeypox infections result in fever, headache, fatigue and swollen lymph nodes, followed by a rash that develops into blisters (pox) on the skin, including in the mouth, on the genitals, the eyes or the soles of the feet.

Monkeypox infections usually develop one to three weeks after exposure, with infections lasting two to four weeks. Most infections are relatively mild, though the blisters can be quite painful. However, depending on the specific strain of monkeypox, the infections can be fatal in up to 10 per cent of cases, although the current outbreak has a lower fatality rate of around 1 per cent.

“Isolation of individuals with rashes or blisters is highly effective at preventing monkeypox transmission”

IS THERE A CURE?

There are a number of therapeutics developed for smallpox that should also work on monkeypox, and several effective vaccines are available for high-risk individuals. In addition, a study carried out in the 1980s at the London School of Hygiene & Tropical Medicine found that previous smallpox vaccination can help to protect against monkeypox. But routine vaccination against smallpox was ended in the UK in 1971, so overall immunity has been declining year-on-year.

During a case of monkeypox, the rash and blisters can be highly infectious, and the virus is typically transmitted through close contact between people. In some cases the virus may spread through the air, though a study led by researchers in Geneva suggests it is far less infectious than COVID-19. Regardless of the type of transmission, isolation of individuals with rashes or blisters is highly effective at preventing monkeypox transmission.

The question on everyone’s mind is why is this current monkeypox outbreak so different from previous ones, and how worried should we be? At the time of writing the answer is that we don’t yet know why this outbreak is different from all the rest.

It’s possible that the recent return to travel and large social gatherings following relaxation of COVID-19 restrictions has resulted in more cases of monkeypox transmission in a short period of time. It is also possible that the virus has changed or mutated in some way that is enabling more transmission, though current data suggests that this strain of the virus is similar to the West African

Monkeypox causes blisters to develop on the skin

strain that has previously caused small outbreaks. Alternatively, this outbreak may be progressing differently due to previous COVID-19 infections. We know that COVID-19 infections can cause dysregulation of our immune system, and recent evidence from a study by Australian researchers suggests that this dysregulation may persist for weeks or months following infection, even in people without persistent symptoms.

It is possible that this immune dysregulation increases susceptibility to infection, facilitates virus transmission or alters the clinical disease. If this is the case – and that is far from proven – then we may see more unusual infectious disease outbreaks in the coming months.

Regardless of the reason for the unusual nature of the current monkeypox outbreak, it is likely that we will see more cases over the coming weeks. People can take as long as three weeks to become symptomatic and can spread the virus for up to a month, so it will take some time before we know the full size and scale of this outbreak. Given that monkeypox mainly spreads through close contact with someone that has the rash or blisters, it is unlikely that this outbreak will become a new epidemic or pandemic.

However, there are risks to individual people and it is important to be aware and cautious. Talk to your doctor if you notice any rashes or blisters/pox on your body, and be cautious before coming into close contact with others. As with COVID-19, remember that misinformation is widely spread, so be careful of what you read on social media. Refer instead to trusted sources such as the NHS.

This is a new and rapidly changing outbreak and the information may change quickly. Stay up to date and remember that the COVID-19 pandemic is still going on, with new immunity-evading variants and a continued need for precautions. Thankfully, the measures that stop the spread of COVID-19 will also stop the spread of monkeypox.

by **DR JEREMY ROSSMAN**

Jeremy is an honorary senior lecturer in virology at the University of Kent.

COMMENT

CLIMATE: COULD 50°C BECOME THE NEW NORMAL?

A recent heatwave in Jacobabad, Pakistan saw temperatures hit a record 51°C – dangerously close to the limit of human survivability

More and more heatwave records are shattered every year. Last month, we saw temperatures max out at around 51°C in central Pakistan, while last year saw a nearly 5°C toppling of the previous temperature record in western Canada. For some of India's current heatwaves, we have estimated that climate change has made them 100 times more likely, and by the end of the century, we predict that heatwave temperatures of 50°C will be an annual occurrence in the region. The numbers vary depending where you are on the globe, but one thing we can be sure about: more extremes are coming.

The feeling of being hot or cold doesn't simply depend on temperature, but a range of weather conditions. Humidity, wind speed, and solar radiation can all add or subtract from our perceived temperature, and in certain combinations, they can be deadly.

WET BULB, DRY BULB

At the heart of this combination is 'dry-bulb temperature'. This is what we normally think of when we say temperature, and what you would measure if you stuck a thermometer above your head and read off the mercury. But meteorologists often prefer to use a 'felt temperature', known as wet-bulb temperature, which is also measured with a thermometer but wrapped in a wet cloth, to mimic many of the same heat transfers that are regulated by our bodies.

Most of us know the uncomfortable feeling of being unable to cool down on a humid night – the same mechanisms are at play here. Physiologically, this makes sense. Humans, and indeed all mammals, sweat to cool down, a process of losing moisture from our bodies. If the humidity is too high, the sweat cannot move from our skin, so this cool-down mechanism is prohibited.

We know the human tolerance level pretty well – it is a wet-bulb temperature of 35°C. At this point, humans cannot survive for more than a couple of hours because we can no longer transfer heat from our body to the environment. This might not sound like much, but the numerical value of the wet-bulb is always lower than that of the dry-bulb (except at 100 per cent relative humidity). This means a 35°C wet-bulb temperature can easily equate to an over 50°C dry-bulb temperature, even at moderate humidity levels.

CDC/PHIL.GOV, GETTY IMAGES

“Adapting to new heat norms is inevitable, but the good news is that we already have a wealth of heat-reduction strategies available to us”

ABOVE
Pakistan’s Sindh province has recently seen record-breaking temperatures

So, have we ever exceeded a 35°C wet-bulb temperature threshold? The answer is yes, but very rarely. There have only been about 10 reported cases, all in the Middle East, in and around India, in Australia and in Mexico. Even when wet-bulb temperatures do not reach this high, the large, densely packed cities in these regions compound the heat-health problem, and so it is commonplace to see hundreds of heat-related deaths every year in some of the major urban centres.

In general, the richer and more modern the city, the less of a problem this is, and in some of the larger Middle Eastern cities they have learnt to adapt very well. Indeed, the locals in Dubai and Abu Dhabi know to dress up warm in the height of summer, because they travel by car from building to building, with the AC maxed out and without ever needing to walk outdoors. The poorer and more rural-based citizens of the world do not have this luxury.

But will climate change make this worse? Given the increase in temperatures, we expect more exceedances of the 35°C survivability threshold in the future, but these cases are likely to remain rare and only occur for a few hours at a time. We expect them to be limited to locations in the tropics and subtropics, and even then only during certain years. We predict that the likelihood of these exceedances significantly diminishes if we can adhere to the Paris Agreement climate goals – that is, keeping the rise in global mean temperature below 2°C.

Even if temperatures do not exceed survivability limits, though, heat can still kill. Adapting to new heat norms is inevitable, but the good news is that we already have a wealth of heat-reduction strategies available to us. Even in Europe, we see many streets surrounded by tall rows of buildings, able to shade inhabitants from the penetrating sunlight. We also see buildings painted in lighter colours, reflecting the Sun’s heat and providing a cooler environment.

For countries closer to the equator, more drastic measures have been implemented. AC, where financially viable, is an excellent option, but many of the poorer countries do not have the power infrastructure to make this technology reliable. One near-universal strategy that has been shown to work is introducing more nature-based spaces, trees, and water bodies in cities. While not always feasible if your climate is not conducive to such ecosystems, where it is implemented it has been shown to include a wealth of physical and mental health benefits.

In this world of ever-increasing urbanisation, we have spent decades paving over nature – now is the time to let nature claim some of that back. **SF**

by **PROF DANN MITCHELL**
Dann is a professor of climate science at the University of Bristol’s School of Geographical Sciences.

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

FIRST TEST

SILENT RUNNING

Can a new boat keep tourists from disturbing the Arctic? p46

FIVE OF THE BEST

RETRO GAMING DEVICES

Step back in time with these cutesified consoles p48

NEW TECH

IDEAS WE LIKE

The gadgets we're lusting after this month p50

Evercade's VS offers a new take on old-school games consoles

VANAMO ONLINE GAME MUSEUM/EVAN AMOS X2

15 years

The length of time the Atari 2600 console remained in production due to its popularity

32.9 million

The number of Nintendo N64 consoles sold over its lifetime (the Game Boy sold 118.7 million)

PREVIEW

This electric-hybrid boat changes marine tourism as we know it

Daniel Bennett hops aboard the maiden voyage of a first-of-its-kind ship that's hoping to lead the conversation on sustainable tourism

At the top of the world a quiet revolution is taking place. In Svalbard, a Norwegian archipelago a little over 1,000km away from the North Pole, a marine engineering company, a boat builder and a tour operator are piloting a scheme that they hope will convince the world – or at least a few more customers – that commercial boats, don't need to be powered by smelly, sputtering diesels. Instead, they could use something altogether more modern: a hybrid-electric drivetrain.

The scheme works as follows: marine engineering company Volvo Penta has built a state-of-the-art, hybrid-electric drivetrain that's fitted to a boat built by Marell. This package is then sold to a tour operator called Hurtigruten, who run Norway's ferries and boat tours in Svalbard. Here's where it gets interesting. Hurtigruten won't be buying the boat, they'll pay for it by the hour.

The aim here is to tempt a marine industry that's sceptical, risk-averse and wary of sinking costs into new tech to test the waters. 'You pay by the hour. We worry about the future', is the pitch in not so many words. Volvo Penta still owns and services the boat's machinery; Hurtigruten just operates it.

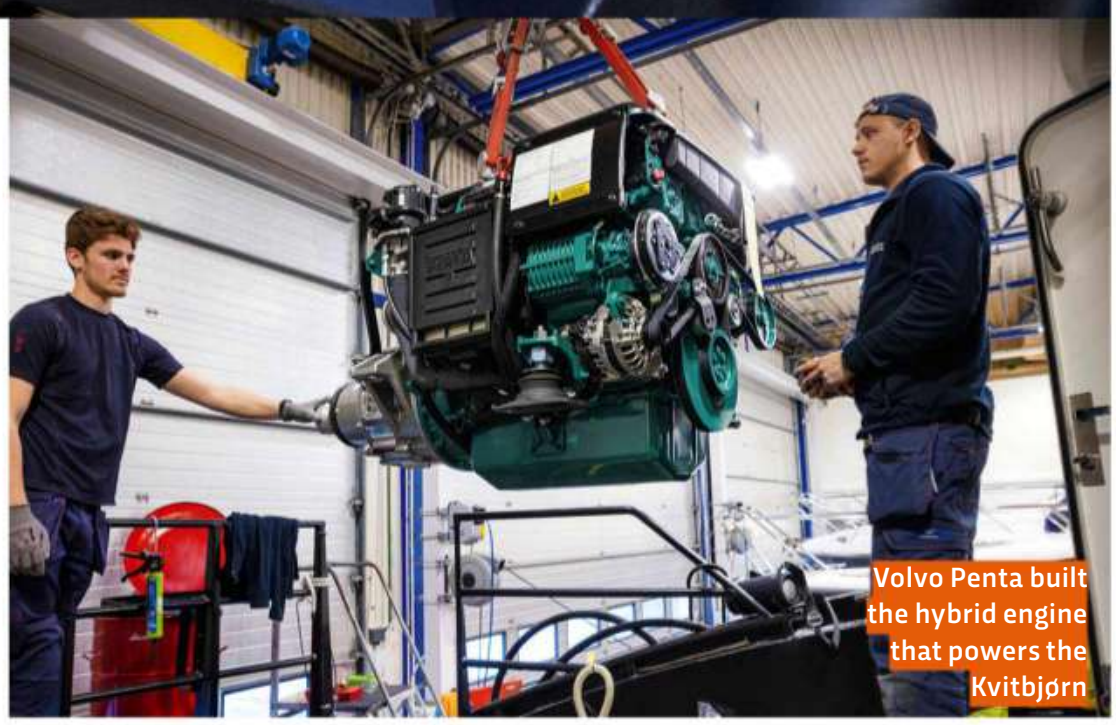
Why test it in the wild, frozen North? Well, whether it was intended or not, the Volvo Penta system makes a lot of sense out here. The Arctic's soundtrack is one of silence. There's almost nothing here to make a noise. To disturb the peace with the chugging of a diesel motor, while trying to sneak up on a polar bear, one of the planet's fiercest predators, seems counter-productive at best. And just as importantly, a boat that makes little noise and has less environmental impact as you explore the archipelago's jaw-dropping beauty will appeal to eco-savvy customers. Plus, if it works here, where the icicles are as tall as people, it should work everywhere else in the world.

Svalbard also makes a lot of sense as an early adopter, since it's under serious threat from climate change. The archipelago is one of the most climatically sensitive areas on Earth. Average temperatures have risen here by 1.7°C in the last decade, twice the Arctic average and seven times the global average. More than anything else, these changes will affect the polar bears who stalk

It's hoped the quiet engine will prevent the Kvitbjørn from disturbing wildlife

Seeing the Svalbard landscape is better in fume-free near-silence

The Kvitbjørn's cockpit has the feel of a gaming set-up



Volvo Penta built the hybrid engine that powers the Kvitbjørn

EVELINE LUNDE, VOLVO PENTA X2, SÖREN HÅKANLIND

the sea ice for seals that come up to rest. As the sea ice recedes, so will the bears. So the people that live here have to deal with a conflict, one that's playing out across the planet: when your livelihood depends on tourism, can you keep earning a living in a way that's sustainable for your, and the planet's, future?

One boat isn't going to answer a question as huge as that, but as I was lucky enough to be invited to see this pioneering boat, I can, at the very least, share my thoughts. There's an obvious parallel in the car industry that's almost a cliché to bring up, but, that said, I hope this could be a 'Tesla' moment for tour boats. The Kvitbjørn (Norwegian for polar bear) is a brilliant innovation that, to this passenger, made a compelling argument.

First off, let's acknowledge a couple things, Kvitbjørn is still a hybrid; there is still a diesel engine for crossing the large expanses of water between peninsulas. In a place where being marooned means risking becoming stuck in sea ice, I can understand why a captain might want to hold on to his engines. The boat also isn't totally silent. Standing on the deck you can hear the whir of the motor and gears as they power small thrusters below, but honestly, I've used louder kitchen equipment.

Out on the sea ice, where the water starts to clump together in crystals and the glaciers glow blue as they meet the coast, the quiet feels like a blanket. The Kvitbjørn feels sympathetic to this, doing its best to give way to the occasion. There's no noxious diesel fumes or noisy engine to ruin the moment. In fact, you don't even need to drop anchor – there's a virtual one. 'Drop' it and the electric thrusters keep the vessel in place, pulsing to stop it running away with the currents. Volvo Penta doesn't know if the boat is quieter below the water yet – and therefore kinder to the sealife than a traditional motor – but is hoping to test it and see how it fares over a reef.

If this does tempt you to sell all your property in order to start operating your own tour boat, then luckily you'd probably be able to drive Kvitbjørn too. I did. There's a traditional wheel, next to a much more clever joystick that lets you rotate the boat on the spot and move side to side without having to turn. It's just like a video game.

So, is this small scheme enough to change the world? Who can say, but Volvo Penta and Hurtigruten believe that there's a huge number of trips – and not just for tourists – that could be powered completely by electricity, and this is a step towards that future. This pilot isn't a one-off. Volvo Penta's ambition is to scale this system across all its machinery and provide buyers with an electric option. And what about that diesel? Well, Volvo Penta is optimistic that greener fuels (not from fossils) will help mariners transition as battery ranges extend further.

Either way, I'm probably not going to look at a trip on a boat the same way again.

The essentials... for retro gaming

Relive your misspent youth with this cutesified gaming equipment that actually is smaller than you remember

Evercade VS

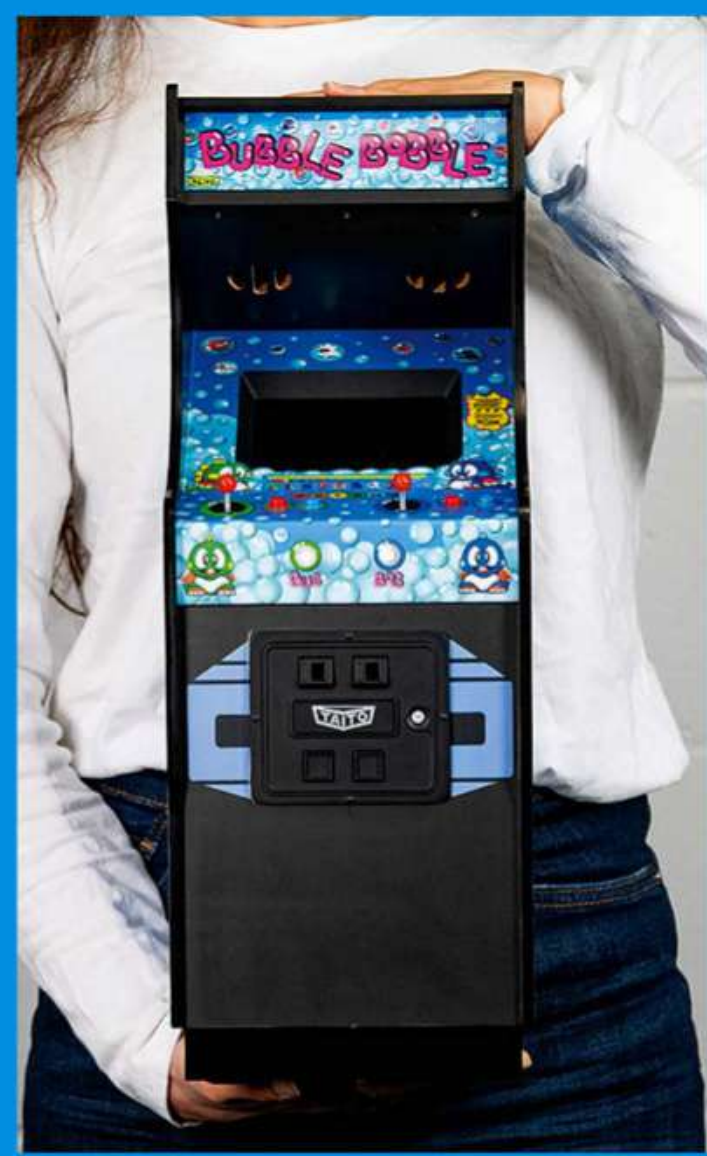
£89.99, evercade.co.uk

While most retro gaming devices take the form of a console with games built into the hardware, the Evercade VS takes a slightly different approach. It isn't devoted to a single gaming platform or company, but instead offers an entirely new cartridge-based console. That means you have to pick up and plug in a cartridge to play a game – just like back in the day. There are eight vintage arcade games included in the pack, but what the Evercade VS really offers is a chance to continually top up your game library with widely available, fairly affordable, boxed cartridge releases that typically contain several games from different publishers that defined gaming's past. A couple of options even include modern indie games. The main unit and the controllers perform well – but we found this isn't as physically lavish as some other options here. As the cart library continues to expand – and with the VS supporting up to four simultaneous players – it really is an amazingly distinct option in 2022.

Bubble Bobble Quarter-Scale Arcade Cabinet

£149.99, numskull.com

The Quarter Arcade range is made up of 1:4 scale working replicas of classic arcade cabinets from the 1970s and 1980s. There's just one game on each diminutive unit and the line-up includes *Space Invaders*, *Galaga*, *Dig Dug*, *Galaxian* and the greedy action puzzlers *Pac-Man* and *Ms Pac-Man*. We opted to try out *Bubble Bobble*, however. The game itself is superb, and performs pretty authentically. But playing it on such a tiny screen with a minuscule (and good-quality) joystick and buttons is truly great fun – although possibly not the best way to master *Bubble Bobble*, admittedly. What most impressed us though is the glorious detail and quality of the cabinet. From the artwork enveloping its wooden construction and the warm, glowing light it emits, to all the amazing details (such the light-up coin return buttons on the front), as seen on the real thing. Everything about it is just right but at charming scale. The *Bubble Bobble* Quarter Arcade, then, is perhaps more of a gloriously detailed, nostalgic, functional display piece than a perfect gaming machine. And we love it all the more for that.



SEGA Mega Drive Mini

£69.99, megadrivemini.sega.com

Recent years have seen a boom in 'microconsoles' and SEGA's Mega Drive Mini is one of the best. It's an almost unbearably cute miniaturised version of SEGA's iconic console. Small enough to easily sit in one palm, the delightfully detailed reproduction exists to provide access to a library of classic games. When it comes to retro gaming, you can't beat original hardware hooked up to an old TV, but that takes money and space. With the Mega Drive Mini, you pop in a power cord, connect it to a modern screen with an HDMI cable, fire it up and a library of 42 built-in games appears before you. Most are hits like *Sonic the Hedgehog*, *Street Fighter II*, *Golden Axe* and *Tetris*, but there are a handful of brilliant, lesser-known cult titles too, such as *Gunstar Heroes* and *Thunder Force III*.

A500 Mini

£119.99, Retrogames.biz

Thanks to the Amiga's status as a home computer, many a kid in the early 1990s tried to convince their parents that owning one was the future of homework. We all knew what we were up to, though – Amigas were sublime gaming machines. And at the start of this year, the most famous Amiga model, the A500, got the microconsole treatment. As with SEGA's scaled-down Mega Drive, convenience and cuteness also define the diminutive A500 Mini, which contains 25 games covering all manner of genres. You also get an Amiga-inspired gamepad and an amazing reproduction of the computer's beloved, blocky 'tank mouse', which you can even use with a modern computer. Our highlight games included *Zool*, *Worms*, *Pinball Dreams*, *Kick Off 2* and *The Chaos Engine*. Alas, the diminutive keyboard isn't functional, being merely for show. But you do get surprisingly nostalgic packaging – we adored the ring-bound manual, the same as found in Amiga boxes all those years ago.

SEGA Astro City Mini

£129.99, funstock.co.uk

Devotees to arcade culture – and the few remaining arcades out there still offering gaming in return for loose change – will certainly know about the original Astro City. The 1993 arcade cabinet put in years of service hosting some of SEGA's most popular coin-op games. Well, now it's available at 1:6 scale and packed with games from SEGA's arcade history. There are some hits among the 37 included, but we found the list of titles almost reads more like an archive of SEGA's arcade history. Many will gravitate to the likes of *Virtua Fighter*, *Space Harrier* or *Altered Beast*, but you also get curios like the extremely minimal *Dottori Kun*; a game sold with normally empty arcade cabinets in Japan to help sidestep a curious tax law that targeted gambling machines. The built-in screen means the Astro City Mini can be played without a TV, but for us it was a bit much to try and play anything deftly in such a small space.

Ideas we like...

Our pick of the month's smartest tech

...Hi-Fi audio without the faff

Got a spare £6,000 kicking about? Well, that will just be enough for you to invest in legendary audio brand Kef's latest speakers. Other than being staggeringly expensive, the LS60 is one of the smartest hi-fi speaker systems available. It uses apparent source technology, which provides the full audio spectrum of lows, mids and highs from a single point rather than multiple ones. This achieves a better immersion for both music and movies and with the LS60, it can be achieved wirelessly, without all the usual gubbins of an amplifier and cables.

LS60 Wireless
£6,000, us.kef.com/ls60-wireless.html

↑

...the perfect drone for travelling

Every year, DJI's Mini series gets smaller while managing to cram more high-end specs into a lightweight (249g) drone that you can chuck in your bag. But with all those improvements, comes an eye-watering price and a growing fear for your financial status if you crash it. The Mini 3 Pro has advanced obstacle avoidance capabilities, a rotating lens so you can film portrait or landscape, 4K video, automatic tracking and the ability to follow a subject. Despite its higher price, this feels like the perfect drone for beginners.

DJI Mini 3 Pro
£709, store.dji.com

↓

...a TV that can roll itself away

Whether it's as flat as can be, styled like a picture frame or tucked into a corner, trying to make your TV as inconspicuous as possible is the new challenge of the 21st Century. The team over at Studio Booboon have committed fully to hiding your TV away with their concept of the 'Totem'. It's an OLED display that doubles up as a soundbar. When you no longer want to look at your TV, it will roll itself inside the soundbar. It's a great idea, but for now, there is no evidence it will ever come to fruition.

Totem
£TBC, studiobooboon.com/work/totem

↑

...the latest edition in Sony's leading headphones

While the naming convention is still just as convoluted, Sony's latest industry-leading headphones are now here, featuring some key improvements, including what Sony is claiming to be some of the best active noise-cancelling technology on the market and a massive 40-hour battery life. For those who can't stomach the price of the Apple AirPods Max, these stand out as the obvious choice for over-ear headphones.

Sony WH-1000XM5
£379, Sony.co.uk

IDEAS WE DON'T LIKE...

...A MESSY MIX OF HEALTH TECH AND FASHION

What do you do when you want to track your fitness, health and sleep, while also letting everyone know you have lots of money? A pricey smartwatch is the first idea that comes to mind, but if you're looking for less value for money, Gucci's new collaboration could be the way to go. Partnering up with the wearable ring company Oura, Gucci is offering a jet-black version of the ring, complete with yellow gold finish, and accompanied by a Gucci-designed charging station. Despite offering the same abilities and features as the original, this will see you paying an additional £590.

Gucci x Oura Ring
£820, Gucci.com

...WHERE NFTS AND CELEBRITY CHEFS MEET

Celebrities and NFTs go together like oil and water, never quite managing to blend into a satisfying result. Despite this, it hasn't stopped big-name brands from trying to break into this new digital world, with the latest being none other than chef Gino D'Acampo. *Gino's Big Town Chef* is a new game that sees players farm, trade and use their cooking skills to become the Big Town's most celebrated chef. It has already pulled in over $6 million in investment of its digital token... known as 'BURB' coin.

Gino's Big Town Chef
Bigtownchef.com

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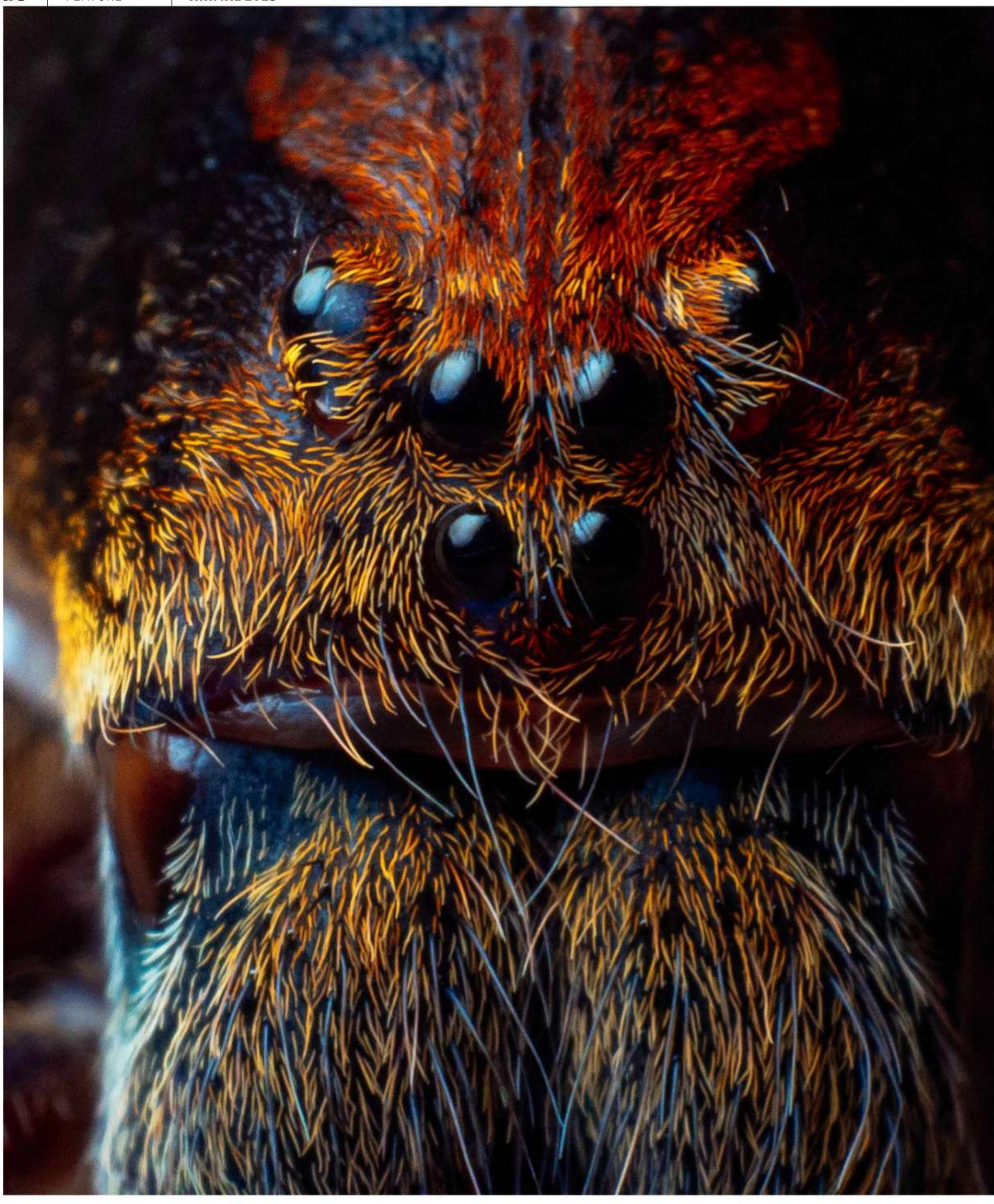

JOAO BURINI/NATUREPL.COM

THE EYES HAVE IT

TWO FRONT-FACING EYES WORKS WELL FOR US BUT NOT FOR EVERYTHING ELSE. THESE ANIMALS HAVE SOME BIZARRE AND BEAUTIFUL EYES THAT LET THEM SEE THE WORLD IN VERY DIFFERENT WAYS

WORDS: DR HELEN PILCHER

HAIRY HUNTER

ORNATE WANDERING SPIDER, BRAZIL

It seems that spiders don't like odd numbers. Two body segments, eight legs, one to four pairs of spinnerets and always an even number of eyes. Most spiders, like this ornate wandering spider, have eight simple eyes, but some have six or two. The way a spider catches its food has a strong influence on the ways these eyes are arranged. Web-building spiders, for example, tend to have smaller eyes that are evenly spaced apart, but the more centrally placed eyes of visual predators, like our friend here, are often enlarged. All the better to glimpse a tasty morsel with! There are principal eyes (the bottom pair here) and secondary eyes (the rest), which differ in structure and function. Principal eyes have sharp vision, along with retinas that can move behind their fixed lenses, helping the spider to track its prey. Meanwhile, the secondary eyes work together to provide a wider field of view, and identify objects and movements of interest.

↑

SEEING RED

RED-EYED TREE FROG, COSTA RICA

The red-eyed tree frog likes to snooze the day away clinging to the underside of a tropical leaf. To stay undetected, they cover their lurid blue and yellow side stripes with their folded limbs, and tuck their bright orange feet under their bellies. A transparent lower eyelid, known as the nictitating membrane, creeps over the eye to camouflage it and keep it moist. If a hungry bird or snake approaches, the membrane lets in just enough light for the amphibian to become aware. Then it's show time! Eyes open, stripes out, orange feet 'in your face' – the frog does its best to dazzle the predator. It's a ballsy bluff, as this frog is neither poisonous nor combative. Its eyes are an evolutionary ruse to scare off predators. The hope is that the assailant will startle long enough for the frog to hop away.

INGO ARNDT/NATUREPL.COM, SHANE GROSS/NATUREPL.COM, SCIENCE PHOTO LIBRARY

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WATCH THE BIRDY

PEACOCK MANTIS SHRIMP, INDONESIA

Why stop at three types of colour receptor, like humans do, when you could have a dozen like the mantis shrimp? It's just one of the many quirks of this crustacean's visual system. Its compound eyes sit on stalks, where they are permanently in motion and rotate independently. They can see colour, as well as ultraviolet and infrared. Each eye has independent depth perception, along with three black slits or 'pseudopupils'. Unlike regular pupils, which are anatomical features, pseudopupils are an optical effect created by the structure of the compound eye. These crustaceans build up a picture of their surroundings by moving their eyes up and down as they scan laterally across a vista. It's a bit like a scanner capturing a photo, only faster and more reliable!

↑

IN THE PINK

PINK LADY MAYFLY, USA

Male pink lady mayflies, like this one, tend to have bigger eyes than their female counterparts, to help them to find a mate in the midst of a frenzied swarm. Each of its compound eyes is made up of thousands of lenses, all pointing in slightly different directions. The eyes can detect movement and colour, albeit towards the blue and ultraviolet end of the spectrum. "This is important for seeing sky," says Dr Luke Jacobus, a freshwater insect expert from Indiana University. "It also helps them orient for moving out of the water when they moult from the nymph stage to the next stage." In addition, mayflies have three much smaller simple eyes: one in the middle, and two on either side of their face. Known as ocelli, these detect light and dark, and possibly day and night.

DAVID FLEETHAM/NATUREPL.COM, ANDY MURCH/NATUREPL.COM

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SEE CREATURE

ELEGANT CONCH, PHILIPPINES

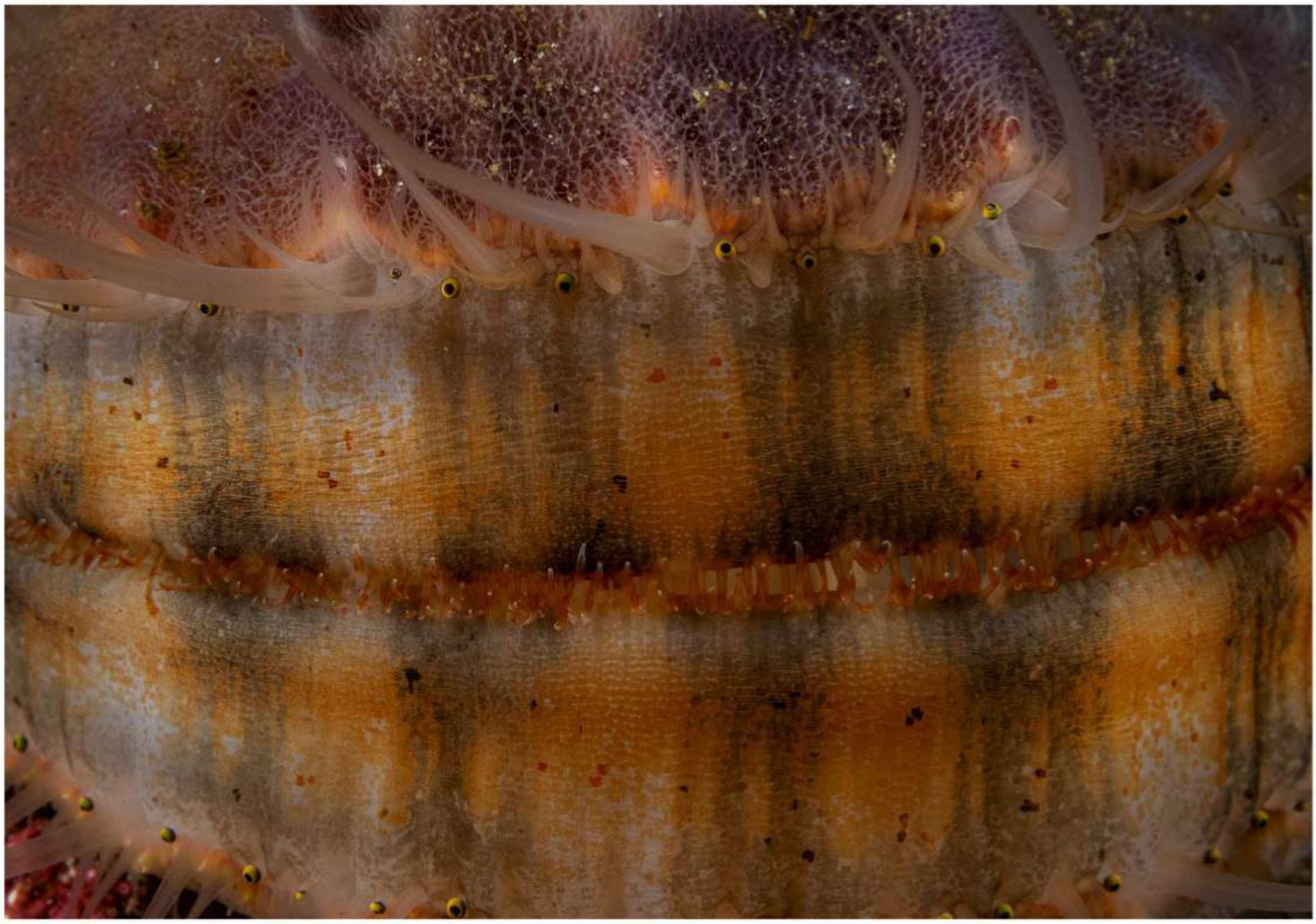
The elegant conch lives in the shallow, well-lit tropical waters of the western Indo-Pacific. The herbivorous molluscs have evolved large eyes and excellent vision. "Conch vision is on a par with that of worker bees, which use their vision for complex flight," says Alison Irwin from the Natural History Museum. "It's really amazing." Their eyes are on stalks, which enhances their field of view, and their retinas contain six different cell types, which is more than has been found in any other gastropod. Irwin has played conches videos designed to mimic a rapidly approaching predator, and found that the animals react strongly to even the smallest of threats. They swim away from predators, such as turtles and crabs, by making large jerky movements, but this uses a lot of energy. It makes sense they have evolved the ability to see fine detail, says Irwin, so they can accurately spot trouble from a distance and not waste resources responding to false alarms.

↑

WATCH IT

BANDED GUITARFISH, MEXICO

Question: How can you tell if a guitarfish can see in colour? The answer, according to Prof Nathan Hart from the University of Queensland, is by training these rays to choose between different coloured cards in exchange for a mashed prawn reward. "Unlike sharks, which appear to be completely colour-blind, guitarfish seem able to see colour," he says. "They are dichromats, so they see the world a bit like a red-green 'colour-blind' human." The silvery part of the eye is the iris, with its three-lobed flap partially covering the jet-black pupil. This can retract or advance to alter the amount of light entering the eye, and the cryptic shape is thought to help with camouflage. With their pebble-coloured hues, these bottom-dwellers blend in well with the ocean floor, but their eyes can be a giveaway. Obscuring the pupil makes the guitarfish harder to spot, while the iridescent iris acts like a mirror, helping the ray to blend in seamlessly with its surroundings.



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JEEPERS PEEPERS

SPINY PINK SCALLOP, CANADA

The spiny pink scallop has hundreds of tiny eyes which line the edge of its two shells. Each eye contains a pupil, a lens, not one but two retinas, and a concave spherical mirror made of guanine crystals. The arrangement has been compared to the optic systems of advanced telescopes, but the end results are less than stellar. Scallop vision is lousy. The mobile marine bivalve mollusc is unable to make out objects, but it can at least sense the difference between light and dark. So, if a large, predatory octopus is looming nearby, it can clatter its shells open and shut like a pair of false teeth, and comically swim away. Some scallops are also able to detect the size and speed of particles moving past them in the water. Scallops are filter feeders, so this enables them to watch the water for feeding opportunities, and then 'open wide' at just the right moment.

by **DR HELEN PILCHER**
(@HelenPilcher1)
Helen is a freelance writer and presenter, with a PhD in cell biology.

→

EYE SPY

PANTHER CHAMELEON, MADAGASCAR

These are the best boggly eyes in the animal kingdom! The eyes of the colourful panther chameleon reside in twin conical turrets on either side of the head. Upper and lower eyelids are joined, leaving just a small pinhole for light to enter. Under the lids, the eyes can rotate and focus independently, giving this reptile an almost 360° view, and the ability to look at different objects on opposite sides of its head. When a juicy insect is spotted, the reptile can then switch from monocular to binocular vision, turning its head so both eyes can focus on the morsel. It's a move that enhances depth perception, and within less than one-hundredth of a second, a sticky tongue has darted out, grabbed the prey and gobbled it down. Compared with other reptiles, their vision is particularly keen. Panther chameleons can spot small insects from up to 10 metres away. **SF**

SHANE GROSS/NATUREPL.COM, CHRISTIAN ZIEGLER/MINDEN/NATUREPL.COM

GREEN, FRIENDLY AND CLEAN: HOW WE COULD REIMAGINE URBAN LIFE AFTER THE PANDEMIC

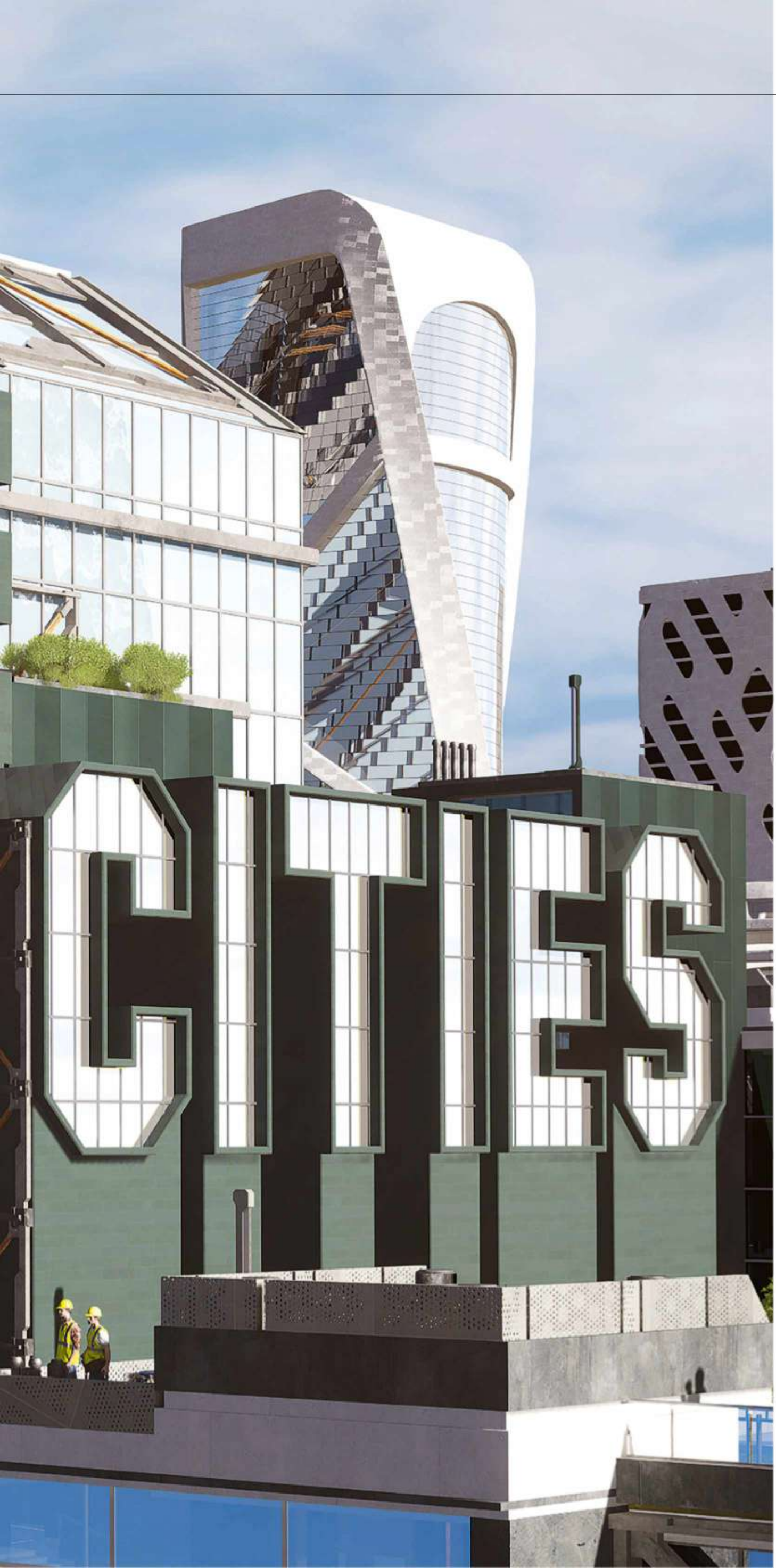


ILLUSTRATION: MAGIC TORCH

by **IAN EVENDEN**

The world's cities are changing. Paris's Champs-Élysées, one of the most gridlocked roads in the world, is going to become a giant garden. Barcelona has closed off its oldest quarters to cars. And now Milan is on the path to becoming the world's first 15-minute city (read on to find out what that means).

It seems the pandemic, for some, became a moment to reimagine how we see the future of our oldest cities. Why? Well, there was a small exodus out of our urban spaces during the pandemic. It was the slightest of pauses in the net migration from rural to urban areas that has taken place for decades. Those who could afford to leave, left. For those who remained, the lockdowns and restricted movement shone a harsh light on most cities' biggest flaws: clogged roads, polluted air and a dearth of green, communal spaces.

Now, it seems that pause has inspired the world's urban planners to rethink how cities around the world can evolve to take a different course. At this fork in the road, here's how our cities could change course after the pandemic.

CREATE 15-MINUTE CITIES

An idea that's catching on in capitals around the world is the 15-minute city. This changes the city from a dense centre with surrounding suburbs into a series of hubs within which are shopping and entertainment facilities. None of these hubs is more than a 15-minute walk or cycle from where people live, and many people may live close to more than one hub.

The 15-minute city idea comes from Colombian academic Carlos Moreno, a professor at the Sorbonne University in Paris, and has caught the attention of Paris's mayor, Anne Hidalgo. In the French capital, the 60km of temporary cycle lanes opened in the city during the pandemic are being made permanent, with more lanes planned for the future.

Creating 15-minute cities relies on new infrastructure, however, to allow people to walk and cycle safely to their destinations, and this can create problems. "A complicated, fast-moving system where 70 million people all, at the same time, understand, agree and

A '15-minute city' version of Paris could see it geared more towards pedestrians and cyclists

GETTY IMAGES X3

LEFT Part of the Rue de Rivoli in Paris was turned into a cycle lane when the city began to reopen after its COVID lockdown

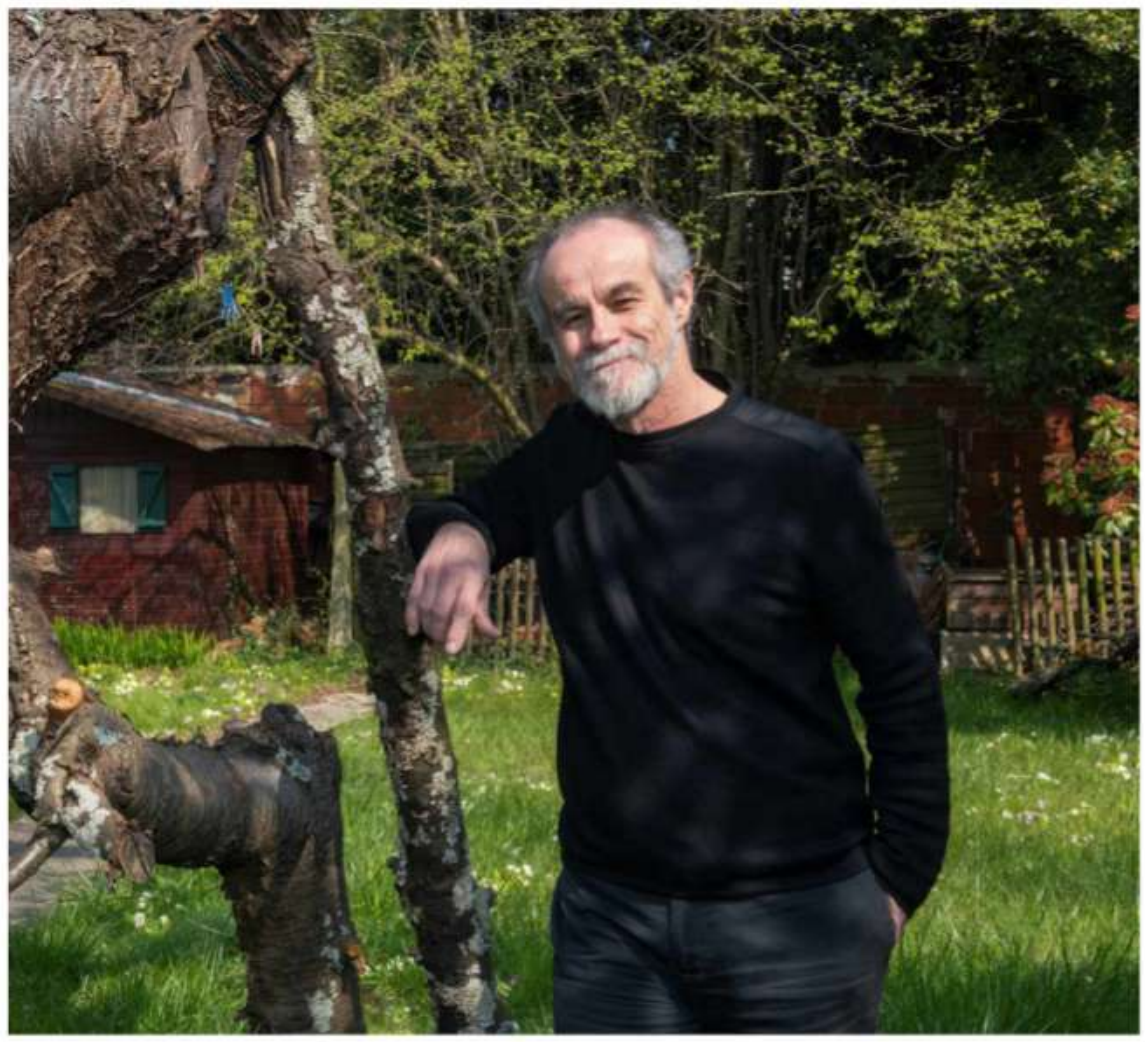
accept the rules is not going to happen," says Dr Ian Walker, professor of environmental psychology at the University of Surrey. "It's far better to have a system where it doesn't matter whether you agree with the rules or not, it's still safe. An extreme example is that pedestrians can't go on the motorway, so drivers can't hit them there. You can start to do things like that in towns if you have a segregated cycle infrastructure, or better still, a segregated driving infrastructure that keeps the drivers safely out of the way of everybody else."

The future goals of the Paris plan echo Walker's sentiments. Enough segregated cycle lanes are being created so that they can be used for most bike journeys of a kilometre or so, while the main junctions that feed traffic into the centre from the Boulevard Périphérique are being made safer for cyclists coming from the suburbs. A huge number of metal arches for chaining bikes to during the day are also expected to appear on the city's streets, along with 50,000 additional cycle parking spaces in car parks and outside housing developments.

Moreno's 15-minute city concept won the 2021 Obel Award, an international prize to honour outstanding architectural contributions to human development. The award's jury recognised the benefits of the 15-minute concept, releasing a statement that said, "The 15-minute city is an intuitive concept and has the capacity to deliver tangible change in people's lives. For these reasons, it has proven easy to translate into political programmes and policies that transform cities."

And it's not just Paris. There has been interest in the 15-minute concept from Latin America, while Moreno has been giving presentations on his ideas in China. Limited trials have also begun in cities such as Houston, Milan, Brussels, Valencia, Chengdu and Melbourne. The C40 Cities, a global network of large cities committed to addressing climate change, embraced the 15-minute city framework in 2020 as part of the Agenda for a Green and Just Recovery.

"THE 15-MINUTE CITY IS AN INTUITIVE CONCEPT AND HAS THE CAPACITY TO DELIVER TANGIBLE CHANGE"



BELOW Prof Carlos Moreno came up with the concept of the 15-minute city

REWILD THE CITY

The COVID pandemic left many people appreciating the outdoors more than ever, finding that time spent in nature relaxed them and improved their mental health. With people unable to travel long distances, they sought green spaces closer to home, such as gardens and the local parkland. There has since been growing calls to rewild our cities so we can continue to enjoy this connection with nature in years to come.

The benefits of being among nature are backed by science too, with studies showing a link between improvements in mental health and nearby green spaces. According to a 2018 trial of 342 participants in the US, feelings of depression decreased by 41.5 per cent for those living near vacant city lots that had been 'greened' than a control group that didn't.

With cities responsible for 80 per cent of the world's greenhouse gas emissions, they contribute heavily to climate change. And with so many built at sea level, they'll

disproportionately feel the effects. An injection of green into urban spaces can help with carbon absorption, improve air quality and mitigate flooding. To this end tall buildings in Singapore are being built with vertical gardens on their sides, while lessons learned from termite nests are being used in Zimbabwe to design buildings that stay cool without air conditioning.

There's also some evidence that poor air quality could affect the microbiome in our digestive systems, causing inflammation of the gut and leading to conditions such as Crohn's disease or appendicitis. The work of Prof Gilaad Kaplan from the University of Calgary suggests air pollution disrupts the protective barriers on the intestinal walls.

A 2017 paper published in *The Lancet* showed that inflammatory bowel disease is more prevalent in industrialised, urban societies, while studies at Ohio State University that exposed mice to air pollution saw them become anxious and depressed, grow more body fat and become less sensitive to insulin than a control group breathing filtered air. A study of more than 600 children in Belgium found that an extra 2.6 points could be added to IQ scores just by increasing the greenery in their environment by 3 per cent, with larger increases at the lower end of the spectrum. Digging into the data, trees were found to be more beneficial to children's development than open land such as farms. Meanwhile, a study from the London School of Economics suggests that crime is lower in areas with trees, with the research finding that for a "10 per cent increase in tree canopy cover, there was a 15 per cent decrease in the violent crime".

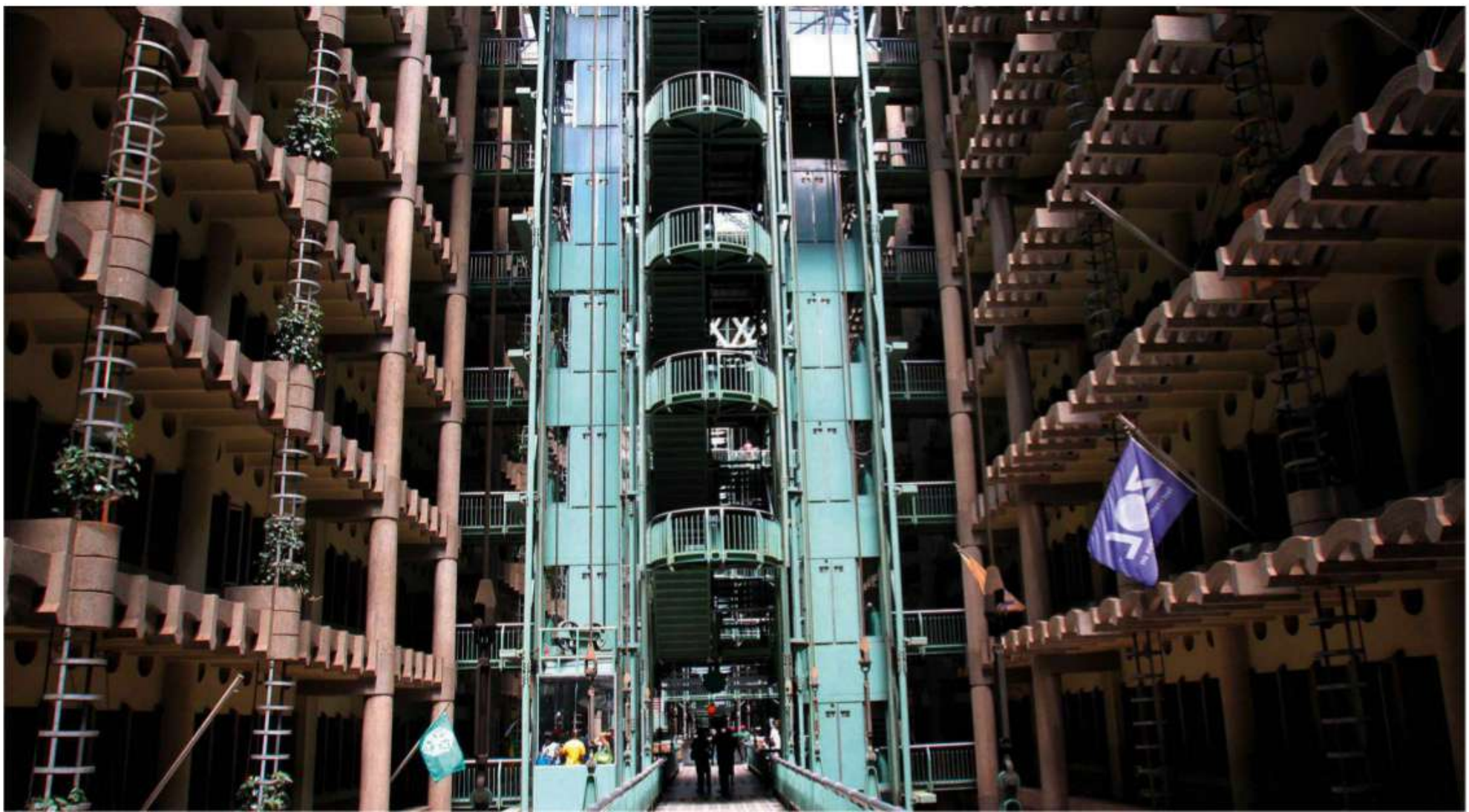
In the UK at least, moves are afoot to increase the green canopy. The Urban Tree Challenge Fund, launched by the UK government in 2019, offers money to communities to plant trees, with the aim of planting 30,000 hectares of trees a year across the UK by 2025.

"TREES WERE FOUND TO BE MORE BENEFICIAL TO CHILDREN'S DEVELOPMENT THAN OPEN SPACES"

FAR LEFT Verdant vertical gardens are incorporated into the exterior of the ParkRoyal Hotel Pickering in Singapore

LEFT The UK's Urban Tree Challenge Fund paid for these saplings that are now growing in St Helens

BELOW Vertical gardens are being established in Harare's Eastgate Mall



ALAMY X2, MCCOY WYNNE

REIMAGINE THE HIGH STREET

Being forced to stay at home during the pandemic led many people to realise that they quite liked remote working, and that they weren't keen to return to their city-centre offices on a full-time basis. This has had knock-on effects, with shops getting fewer customers, and employers starting to wonder why they're renting all that expensive city centre office space.

So how could our city centres change? One idea is to turn them into more active areas, dedicated to doing rather than just buying. That means an increase in cafés, bars, restaurants and cinemas. Post-COVID, open-air markets are increasingly seen as safer places to shop than retailers based indoors, and providing public high-speed internet access on shopping streets could encourage shoppers to linger at a café and maybe work there, rather than going home after buying what they need.

Digitally enabled high streets have also been proposed, which would use sensors to monitor traffic and pedestrian levels to predict when the best times to miss the crowds are.

One word that crops up a lot when talking about the future of cities is 'local'. The idea of making city centres 'more local', by encouraging the return of food shops selling locally sourced produce rather than chain stores, is frequently mentioned. Chain stores were already in decline before the pandemic hit, seeing a 6 per cent drop since 2017 according to figures from Deloitte.

One obstacle to changes like these, however, is human nature. We're so used to our cities being the way they are that we can't always envisage them being any different, or better. "Some people call it the reverse causality hypothesis," says Walker. "This suggests that, whatever your environment is like, you tend to think it's good. Your attitudes tend to be shaped by the environment more than the other way around. If your environment makes it easy to walk to the shops and makes it harder to drive, then you might grumble at first, because people don't like change, but the chances are that a few months in, you'll be doing it, so therefore you'll like it."

"ONE IDEA IS TO TURN CITY CENTRES INTO MORE ACTIVE AREAS, DEDICATED TO DOING RATHER THAN JUST BUYING"

ALAMY, AIRBUS

A SOLUTION FOR THE LAST MILE?

One of the most important changes cities must make to improve life in them is to separate people from their cars. Even when you have a strong public transport system moving people between population hubs, the last mile – that section between the railway station and someone's home, for example – can lead to car use if it's considered too far or too dangerous to walk.

The idea of a low-traffic neighbourhood (LTN) – where cars are banned from quieter 'rat runs' to keep them on the major routes – has taken off in parts of the UK. LTNs attempt to filter out cars from residential streets using bollards, camera-controlled gates or even planters full of flowers placed across the road, while pedestrians, cyclists and emergency vehicles can still pass. London had almost 3,700 such schemes in 2021, with as many as 25,000 traffic filters in place across the UK.

Analysis for the active transport charity Sustrans found that "driving a mile on a minor urban road is twice as likely to kill or seriously injure a child pedestrian, and three times more likely to kill or seriously injure a child cyclist, compared to driving a mile on an urban A-road," and that heavy car traffic in residential areas can lead to a rise in social isolation. LTNs reduce this danger, leading to a three-fold reduction in injuries, and have been shown to increase the number of visitors to local businesses.

Also popular are e-scooter hire trials, which are taking place in towns and cities including Middlesbrough, Bristol and Chelmsford. The trials see gaggles of electric scooters available to be picked up from street corners. The scooters are hired using an app and then, once they're finished with, parked elsewhere inside the trial area, where they're collected and recharged by the hiring company.

A Department of Transport report on e-scooter use found they were "widely perceived to have environmental and convenience benefits," but suffered from comparisons to children's toys. The trials are slated to continue until November 2022, at which point we'll be able to get a better idea of whether they're a feasible way to improve transport and emissions in our cities.

But that's not all. The world's first hub for demonstrating electric air taxis and drones opened in Coventry earlier this year. The taxis and drones based at the hub all take off and land vertically like helicopters and are being used to travel short journeys or deliver cargo. Urban-Air Port, the company behind the hub, has plans to open more than 200 of these 'vertiports' worldwide in the next five years. Urban Air Port founder Ricky Sandhu described it as "the starting gun for a new age of transport, an age of zero emission, congestion-free travel between and within cities that will make people healthier, happier and more connected than ever before".

Weaning us off our car addiction is one of the more difficult barriers standing between us and healthier cities. Asked if the car is the number one problem with modern city living, Walker replies, "I think it is, because they become an accelerator of other problems. [Cars] permit living a long way from work, for example, and this, in turn, means people are less likely to socialise with people they work with. Cars also permit local authorities to build massive, horrible shopping centres on the edge of town that you can't get to without a car."

So while change in our cities is possible, it will require political will as well as the support of the people living in those cities in order to happen. But the first step that needs to be taken will be to tackle the dominance of the car. **SF**

by **IAN EVENDEN**
(@ievenden)
Ian is a freelance science and technology writer. .

RIGHT The JET fusion reactor in Culham, Oxfordshire

THE NEW AGE OF FUSION

FOR DECADES, THE TECHNOLOGY TO DEVELOP CLEAN, SAFE FUSION POWER HAS REMAINED TANTALISINGLY OUT OF REACH. NOW, THOUGH, A NEW BREED OF START-UPS COULD HAVE CRACKED IT AT LAST. WILL WE FINALLY BE ABLE TO WAVE GOODBYE TO FOSSIL FUELS?

by **DR STUART CLARK**

SPINNER
SPINNER
SPINNER

Flick through any collection of popular science magazines from the last 50 years and the chances are that you will encounter a feature about nuclear fusion. Nuclear fusion is the process of joining lightweight atoms together to release energy; it is the reason the Sun and the rest of the stars shine, and recreating that process on Earth promises an abundant form of low-carbon energy.

As you look through the archival material, keep an eye open for when the pundits think fusion might arrive. It's an old joke that whatever the decade of the publication, fusion has always been "about 20 years away". Yet despite five decades of effort, no fusion plant can yet produce more energy than it takes to start the reaction.

But don't let that bare fact make you think that fusion is as far away as ever. There has been a sea change recently that has shrunk the 20-year horizon to a mere decade away. For a start, there has been an increase in our understanding of the science of fusion. Second, there has been an undoubted set of technological breakthroughs. But it is the third reason that may be the deciding factor: a change in mindset.

"The most important single thing that's changed in the world of fusion, in my opinion, over the last decade, is the very clear realisation that we need fusion," says Tim Bestwick. He is the chief technology officer and director of strategy, communications and business development at the UK Atomic Energy Association (UKAEA).

He explains that the two principal factors in this realisation are climate change and energy security. In regard to climate change, fusion offers an abundant source of low-carbon energy that can be used in combination with renewable energy sources such as solar and wind power. This has been accepted for years now, and while energy security has also been talked about for a long time, the sharp need for it has only just recently come into focus, particularly with Russia's invasion of Ukraine causing many countries to rethink how they buy in energy and fuel from foreign powers. This all loads the dice in favour of fusion.

The UK's fusion effort is headquartered at the Culham Centre for Fusion Energy in Oxfordshire. This is the home of a long-running experimental fusion reactor called JET, the Joint European Torus. JET is a tokamak, a five-metre-wide doughnut-shaped vessel. The name derives from a Russian word meaning 'toroidal chamber with magnetic field'. Since starting operations in 1983, it has made major advances in understanding both the science of nuclear fusion and the engineering required to make it happen. And for inspiration, the researchers need only look up into the sky...

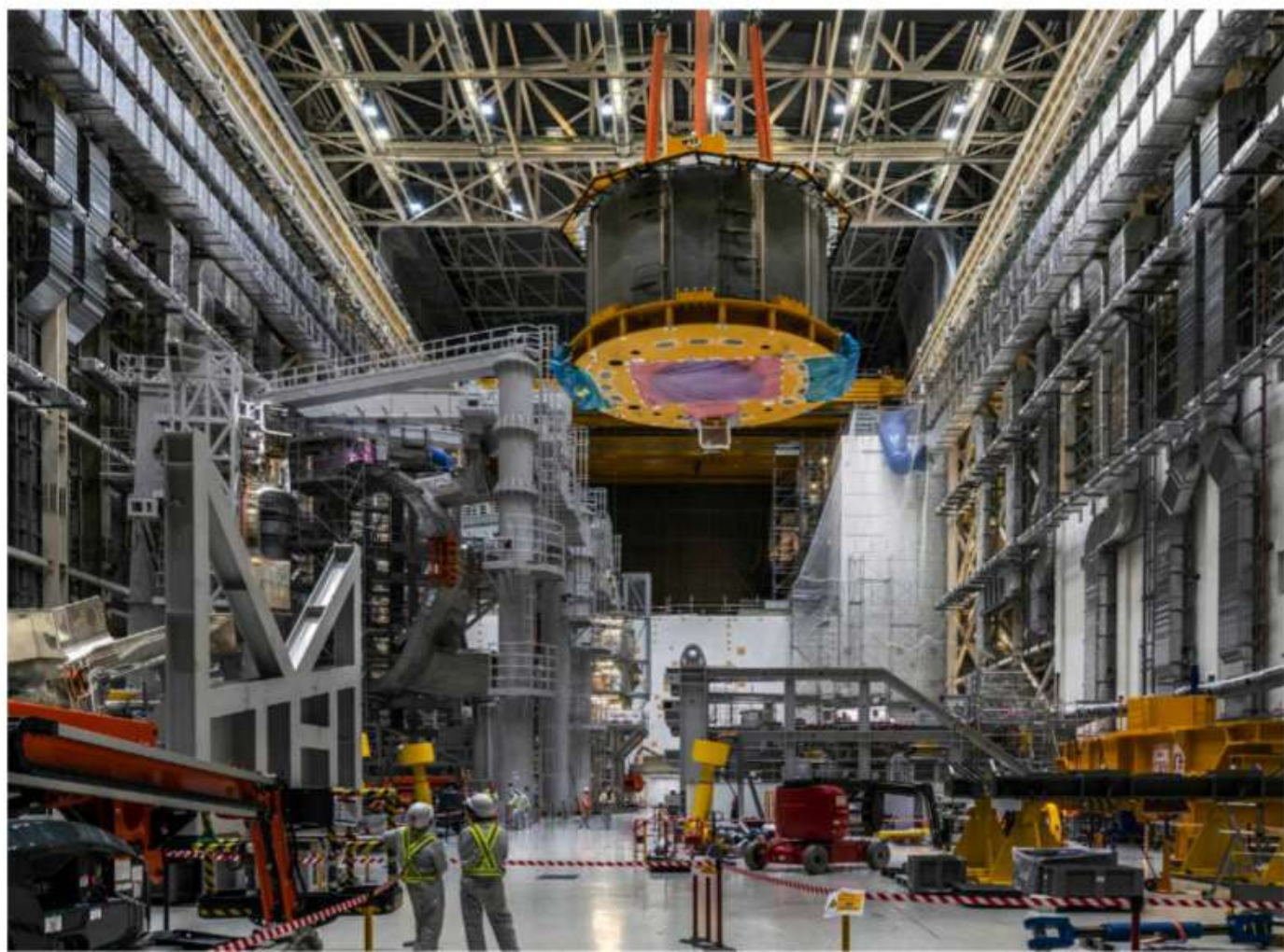
"THE MOST IMPORTANT SINGLE THING THAT'S CHANGED IN THE WORLD OF FUSION, IN MY OPINION, OVER THE LAST DECADE, IS THE VERY CLEAR REALISATION THAT WE NEED FUSION"

CREATING THE SUN ON EARTH

The Sun is the nearest natural fusion reactor to Earth. Deep below its glowing surface, the temperature soars to 15 million degrees Celsius, and the pressure and density is similarly gigantic. Under these conditions, fusion naturally occurs. It starts with hydrogen and proceeds through a series of interactions that force the hydrogen nuclei together. First the reactions build isotopes of hydrogen and helium, and then ordinary helium itself.

For an artificial fusion reactor, it is impossible to recreate the kinds of pressures and densities found inside the Sun. Inside JET, for example, the gas density rarely rises above that of the ordinary air outside, and so to compensate, the temperature must be boosted to more than 100 million degrees Celsius. At such temperatures, the gas becomes electrically charged. This state of matter is known as a plasma, and because of its electrical charge, it can be controlled by magnetic fields. The magnetic field is essential because no material can contain a gas at more than 100 million degrees Celsius. The magnetic field accelerates and controls the flow of the plasma within the reactor, allowing the particles to fuse and release energy.

"JET has been an extraordinary machine. It has hugely outlived its expected life. I think its significance is around the fact that it is a deuterium-tritium machine," says Bestwick.



RIGHT A technician operates JET's remotely controlled MASCOT robotic arm

BELOW The ITER tokamak is currently under construction in France

JESSE WILD PHOTOGRAPHY, THE ITER ORGANISATION

Deuterium and tritium (DT) are isotopes of hydrogen. After a number of experiments at JET over the years, it's clear that deuterium and tritium will be the fuels that make fusion viable. So now that the science is sorted, the next step is for the engineers to actually build a reactor capable of generating more energy than it needs to run. This is where ITER comes in.

ITER is a tokamak twice the diameter of JET. It is being built in southern France by a consortium of 35 countries, including the UK. The tokamak itself is scheduled to be completed this year, but then it must be encased in its surrounding machinery. Operation is expected to begin in 2025, followed by a decade of gradually ramping up the reactor to its full capacity. Eventually, ITER is expected to be able to return 10 times the energy required to start the process.

Beyond ITER, UKAEA is also designing a reactor called STEP (Spherical Tokamak for Energy Production) that will be the world's first prototype nuclear fusion energy plant. The site for its construction will be chosen by the end of this year. Construction is slated to begin in the 2030s, with commissioning several years later. And they are not alone.

ABOVE LEFT
A small robotic arm being tested at RACE (Remote Applications in Challenging Environments)

ABOVE RIGHT
A giant robotic arm, similar to those needed for fusion reactors, being put through its paces at RACE

SHARING KNOWLEDGE

The diffusion of knowledge about what it takes to spark fusion, combined with the march of technological progress, mean that building a commercial fusion power plant is now largely an engineering challenge, rather than a leap into the scientific research and development. As a result, the last few years have seen a profusion of private companies interested in developing their own approaches to fusion.

"Twenty years ago, fusion was the preserve of governments. Now there are more than 25 private fusion companies around the world and they're attracting huge amounts of investment," says Valerie Jamieson, who manages the newly inaugurated Fusion Cluster at Culham.

Aiming for its official launch later this year, the Fusion Cluster is attracting start-up companies interested in building or contributing to fusion reactors. They will be housed next to JET's facilities, allowing expertise and opportunities to build up in one place. It's a tried and tested formula.

"The best-known technology cluster is Silicon Valley," says Jamieson, "Having all your customers and collaborators nearby just oils the wheels and makes everything run more smoothly."

Another UK science cluster exists at the Harwell Science and Innovation Campus, also in Oxfordshire. It started around a decade ago with a handful of companies and now boasts more than 100 space organisations. Of course, when it comes to private space companies, the most obvious success story is Elon Musk's SpaceX, which now routinely ferries astronauts to and from the International Space Station. This is the sort of success that the cluster hopes to emulate.

"TWENTY YEARS AGO, FUSION WAS THE PRESERVE OF GOVERNMENTS. NOW, THERE ARE MORE THAN 25 PRIVATE FUSION COMPANIES AROUND THE WORLD"

The successes have already begun for two of the more established companies in the cluster. Tokamak Energy (see box, p76) recently achieved the necessary plasma temperature for fusion

CASE STUDY: FIRST LIGHT

IMPLODING FUEL TO RELEASE ENERGY

There are a number of approaches to nuclear fusion. Beyond the swirling plasmas of the tokamaks, another approach is called 'inertial fusion'. In this method, a fuel pellet is compressed to temperatures and densities that allow fusion to take place.

At the National Ignition Facility (NIF) in the US, the compression is achieved by a bank of 192 extraordinarily powerful lasers. At First Light Fusion, a private company that is part of the Culham fusion cluster, it is achieved by shooting a target containing the fuel with a projectile fired from a hyper-velocity gun. The projectile is accelerated to 6.5 kilometres per second, but when it hits the target, the top secret design focuses and amplifies the impact to make the fuel implode at over 70 kilometres per second. This triggers fusion and releases a pulse of energy.

First Light founder Nicholas Hawker heard about fusion while doing his A-Levels in the early 2000s, but it was not until his PhD that he took up the mantle to study how to advance inertial fusion, which back then was a completely new approach. "Being off the edge of the map and finding new ways of doing things is what really appealed to me," says Hawker.

Now that the technology has been shown to work, First Light is designing a demonstrator reactor to be built in the second half of the 2020s. First Light is also working towards completing a pilot power plant in the 2030s, in line with other fusion start-ups and government-run initiatives.

JESSE WILD PHOTOGRAPHY X4, FIRST LIGHT FUSION

ABOVE LEFT Alex Meakins (left) and Matthew Carr are working on artificial intelligence that could, in time, be used in the fusion reactors

ABOVE RIGHT The MASCOT robot arm can snake its way into the tokamak at JET, to carry out routine maintenance work

in their one-metre-wide reactor, and First Light Fusion (see box, left) achieved fusion for the first time using a different approach from tokamaks.

And it is not just reactor companies that the cluster wants to attract. It also wants companies that can provide essential services for the reactors. Two of those essential services are robotics and artificial intelligence.

HELPING HAND

Just across the campus from JET is the UKAEA's Remote Applications in Challenging Environments (RACE). Inside their hangar-like work area, a giant robotic arm is being tested. Once the reactors are up and running, humans will not be able to enter the reactors to perform maintenance. This is because deuterium-tritium fusion produces its energy in the form of neutrons, which create high levels of short-lived radiation. So robots will perform the tasks that humans cannot. This already happens at JET, where a 12-metre-long robotic arm with two 'hands' is remotely operated by a team of technicians. Called MASCOT, it can snake its way into the tokamak and replace wall tiles, tighten screws or remove worn components. While the technicians are highly skilled at controlling the arm – they play *Jenga* with it as part of their training – it is still a slow process. Therefore, similar but more sophisticated devices for ITER will be needed.

In the high-radiation environment of the reactor, electronics can be swiftly degraded.

CASE STUDY: TOKAMAK ENERGY

SMALL REACTOR, SEARING TEMPERATURES

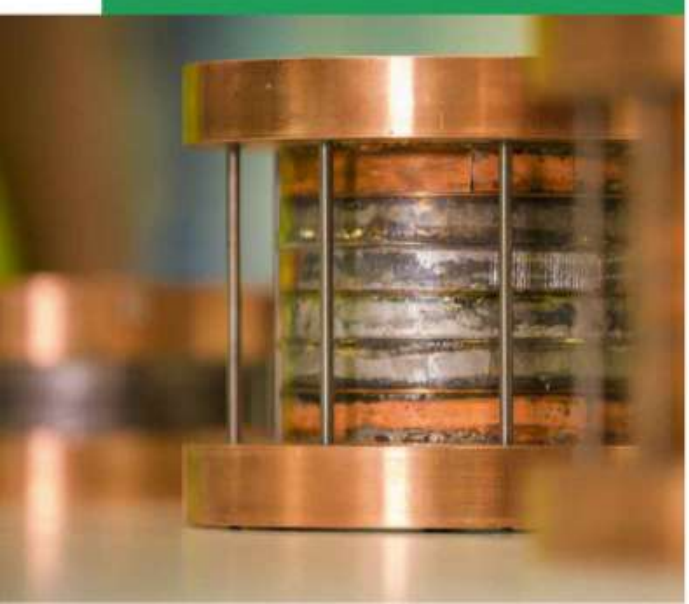
The stronger the magnetic field of a tokamak, the more control it can exert over the plasma, and so the smaller the reactor can be. Tokamak Energy, in common with other labs around the world, has developed strong devices called high-temperature superconducting (HTS) magnets. These produce magnetic fields almost a million times stronger than the Earth's natural field.

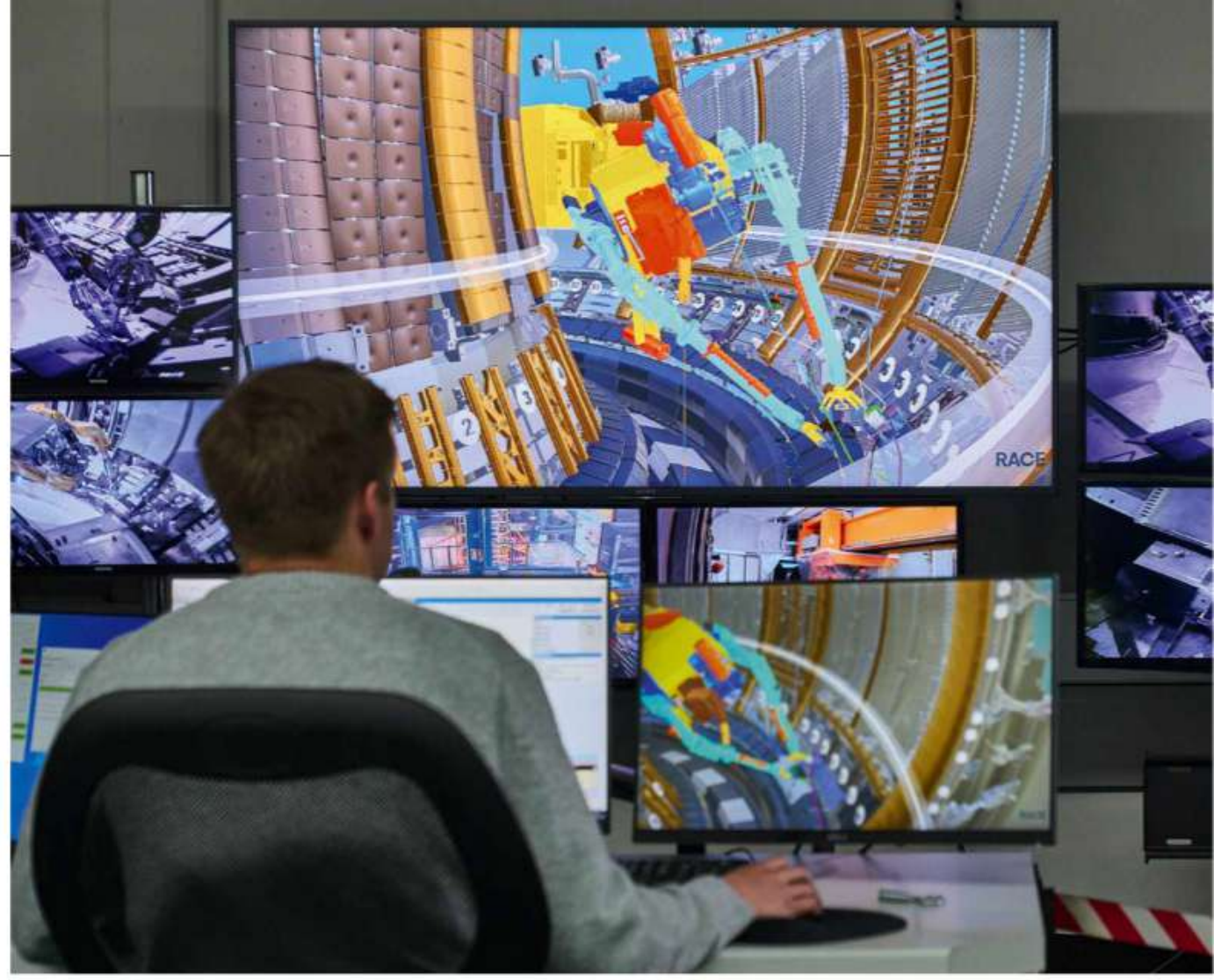
Tokamak Energy recently achieved a plasma temperature of 100 million degrees Celsius in a small reactor built entirely with private funds. In total, the reactor is about four metres high and three metres across, but its volume is 30 times smaller than any other that has achieved that temperature. Now, the researchers plan to build a new reactor using the HTS magnets they have developed. It should be a game changer.

"You can get high performance in smaller devices. You can learn faster, the cost of devices goes down, you're closer to an ultimate commercial goal," says David Kingham, the executive vice chairman and former chief executive officer.

He points out that while experimental plants such as ITER are vital for investigating the science of fusion, it is the smaller, cheaper reactors that will turn the technique into viable power stations.

"Our 10-year goal is for a pilot plant using the technology that would scale into a commercial power plant. Then within five years of that, so within 15 years from now, start to deploy power plants globally at scale," says Kingham.





ABOVE Operators using the MASCOT robotic arm

This is why the robotic arm being tested at RACE is covered in dots, the positions of which are precisely measured by special cameras. When the arm is stressed by heavy loads or movement, the pattern of dots distorts slightly. This is measured by the cameras and can be translated in to a kind of 'pain map' of the arm, showing how it is performing. If the system works, the vulnerable electronic sensors inside the arm can be stripped out, making the system cheaper to manufacture. As an added benefit, knowing when you are approaching the design capabilities of your machine will allow it to be used to its utmost efficiency.

"The motive for using robotics always comes down to safety, productivity or both," says Robert Buckingham, the director of RACE. And the applications of the robotics being developed here spin out far beyond fusion. They could be adapted for

JESSE WILD PHOTOGRAPHY X3, TOKAMAK ENERGY

"THE APPLICATIONS OF THE ROBOTICS BEING DEVELOPED HERE SPIN OUT FAR BEYOND FUSION. THEY COULD BE ADAPTED FOR ANY HAZARDOUS ENVIRONMENT"

any hazardous environment: underwater or in space for example. And while the actual robot for these environments may look very different, what is 'under the hood' is remarkably similar.

"You've got sensors that are looking at what's around you, and you've got a computer to make decisions, and motors to move the robot. There's an awful lot of commonality," says Buckingham.

ADD SOME AI

Hand-in-hand with making these robots as responsive and autonomous as possible is artificial intelligence. Fusion cluster company Luffy AI is the brainchild of data scientists Matthew Carr and Alex Meakins. The pair met while working on Culham's other fusion reactor, MAST (Mega Amp Spherical Tokamak). They realised that controlling the conditions in a fusion reactor needed AI, yet current systems had hit a wall. While AI is great in the digital world, at recognising faces, for example, it was not making such advances when used to control pieces of equipment such as robots or reactors.

After analysing the problem, Carr and Meakins decided that the basic problem was that traditional artificial intelligence systems stop learning once they have been trained. If they encounter an unknown situation, they flounder. To solve this problem, they have coded the machine equivalent of neuroplasticity, the process by which we adapt our behaviour to the environment we find ourselves in. They are currently training drones how to fly, so that if a rotor is lost, the machine will invisibly adjust and the user will notice little to no difference in the handling, although clearly performance will be affected. In the future, one can imagine fusion reactor control programmes that invisibly adjust to the rapidly altering conditions inside the plasma, to maintain the highest fusion efficiency possible. It's heady stuff. A bold, inspiring future is being created at Culham, and it is promised to be closer than we ever thought.

If things continue to go as planned, then in 50 years' time when someone comes across this article, they will realise it was written at a turning point when fusion stopped being "20 years away" and instead was just around the corner. **SF**

BELOW LEFT
A replica of the JET tokamak has been built to allow operators to practise using the MASCOT robotic arm

BELOW RIGHT
Inside the replica of the JET tokamak

by **DR STUART CLARK**
(@DrStuClark)
Stuart is an astronomy writer. His latest book is Beneath The Night: How The Stars Have Shaped The History Of Humankind *(£9.99, Faber).*

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Q&A

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... HOW DO YOU THICKEN A SAUCE?
... WHAT'S THE DIFFERENCE BETWEEN AN OCTOPUS AND A SQUID?
... WHY DO ANIMALS MIGRATE?
... DO WE GET MORE BITTER AND CYNICAL AS WE GET OLDER?
... IS IT TRUE THAT YOU CAN BITE THROUGH A HUMAN FINGER AS EASILY AS A CARROT?
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Science and technology writer

PETE LAWRENCE
Astronomy writer

DR EMMA DAVIES
Food chemist

DR CHRISTIAN JARRETT
Psychologist and neuroscientist

HAYLEY BENNETT
Science writer and editor

DR HELEN PILCHER
Biologist and science writer

DR NISH MANEK
GP and health writer

DR HELEN SCALES
Marine biologist and writer

DR STEVE BRUSATTE
Veteran palaeontologist

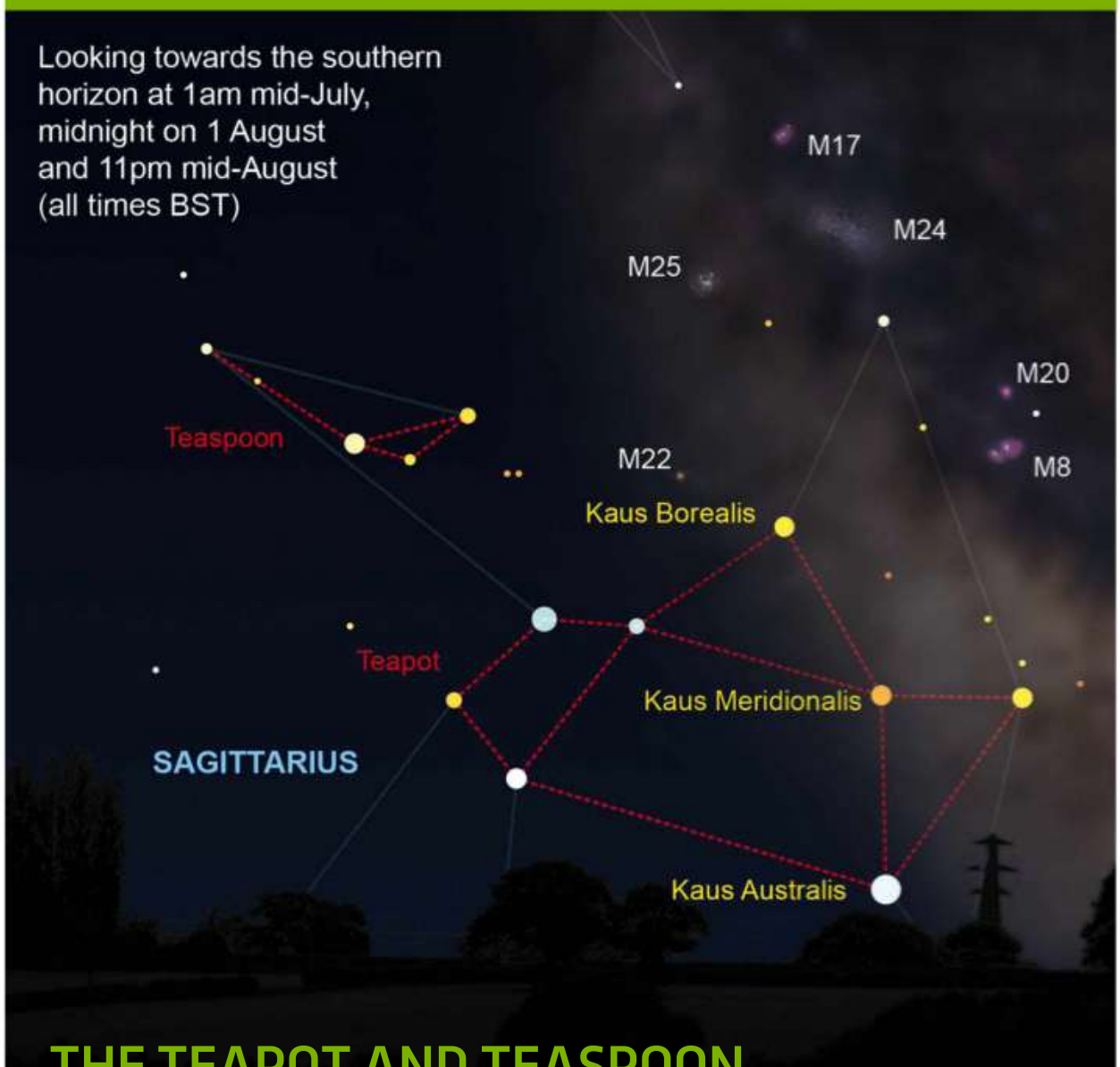
ILLUSTRATION: DANIEL BRIGHT

LILY WILLIAMS, LONDON

WHY ARE PEOPLE WHO HUMBLEBRAG SO ANNOYING?

The definitive research on the topic remains a 2018 paper by psychologists at the University of North Carolina and Harvard Business School. They identified that there are two types of humblebragger and that the most annoying kind is the complain-bragger. They say things like, "I never have time for myself because my friends want to see me all the time." Only marginally less annoying is the humblebragger who deploys false modesty, such as "I don't understand why I keep getting hit on". Both kinds of humblebragger are seen as less likeable and competent than more straightforward self-promoters, and the key reason is that their complaints and modesty come over as totally fake. ***CJ***

ASTRONOMY FOR BEGINNERS



THE TEAPOT AND TEASPOON

WHEN: JULY AND AUGUST

At this time of year, low above the southern horizon, lurk two tea-related asterisms. An asterism is a pattern of stars which hasn't been officially recognised. In essence, anyone can create an asterism, but only the really relatable ones gain traction and stick. The tea-related asterisms both belong to Sagittarius the Archer.

Sagittarius is so far south that from the UK it never fully rises. The bit that does rise contains a set of stars that resemble a teapot. It may take you a few minutes to sort out the view, but once you do, the pattern is quite striking. The two stars that form the apex and western base of the lid, along with the star marking the base of the spout, form the mythological centaur's bow. They are called, from north to south, Kaus Borealis, Kaus Meridionalis and Kaus Australis. 'Kaus' means 'bow', so here you have the northern, middle and southern bow.

If you have binoculars, take a look at where you'd expect to see the steam rising out of the teapot's spout. This is a part of the sky where you can see a lot of deep-sky objects. This is because when you look out into space in this direction, you're facing the very heart of our Milky Way. Here you'll find the bright Lagoon Nebula (M8) and fainter Trifid Nebula (M20) above it, together with numerous rich clusters and star cloud regions further to the north.

To the northeast (upper-left) of the teapot sits a fainter and smaller asterism which is known as the Teaspoon. Although together the Teaspoon and Teapot may appear to trivialise the majesty of one of the night sky's constellations, their purpose is to make it easier to navigate around what would otherwise be a visually confusing part of the sky. *PL*

EMMA BRANDON, ANGLESEY

DO DOGS ACTUALLY ENJOY THEIR FOOD WHEN THEY EAT SO FAST?

Ask your dog! He or she will almost certainly respond with an enthusiastic tail wag. Flavour is the combined effect of taste in the mouth and smell in the nose. Dogs can detect savoury, sweet and bitter tastes, and although they have fewer taste buds than us, this is more than made up for by their surfeit of olfactory receptors, which outnumber our own by more than 20 to 1. If it looks, however, like your dog is bolting its dinner without tasting it, then it's probably a Labrador. Scientists have identified a genetic mutation, common in Labradors, that is associated with both obesity and being obsessed with food. ***HP***

PAUL MOORE, CAMBRIDGE

HOW FAR DOES MY COMPUTER MOUSE MOVE?

I can't tell you how far your mouse moves, but I can tell you the distance that mine moved because I installed a little app that measured every last centimetre. In one continuous hour of working, my mouse moved 123.76 metres. For an entire week, my mouse moved 2.5 kilometres. I clicked my mouse 10,695 times in the same period. Scale it up to a year and my mouse would travel the distance from Bristol to Birmingham! It's a fun thing to try, but be aware some apps like this steal your passwords, so don't use them while working on anything important – my measurements were made under controlled conditions. ***PB***

GETTY IMAGES X2 ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT

ADAM JARRETT, IPSWICH

IS THERE SUCH A THING AS LEFT BRAIN VS RIGHT BRAIN?

You may have heard the saying that people are either 'left-brained' or 'right-brained', meaning that one of the two brain hemispheres is dominant. Right-brained people are often described as creative and artistic, whereas left-brained people are thought of as analytical and mathematical.

It is true that different brain regions show specialisation for particular tasks, such as language or visual processing, but there is no evidence that people have one dominant hemisphere or that hemisphere specialisation is linked to personality.

The two hemispheres of the brain are connected by a bundle of nerve fibres called the corpus callosum, allowing the two hemispheres to communicate and work together. This makes it difficult for scientists to study one hemisphere in isolation. Much of our understanding of the functional differences between hemispheres has come from studying stroke patients and so-called 'split-brain' patients, whose corpus callosums have been severed, usually as a treatment for severe epilepsy.

These studies showed, for example, that the main language centres of the brain are usually located in the left hemisphere, and that each hemisphere is responsible for the motor functions of the opposite side of the body. These real differences might be the origin of the left-brain right-brain myth. However, activities like maths or art are so complex that they require contributions from both hemispheres.

Brain imaging and electroencephalography (EEG) have identified hemisphere asymmetries for particular tasks, such as word comprehension and forming mental images, indicating that different hemispheres have different strengths and weaknesses. But the right hemisphere is still capable of 'left-brained' tasks, and vice versa. These task-specific asymmetries don't appear to translate into dominance of one hemisphere over the other, either: a 2013 study of more than 1,000 children and adults found no evidence for overall left- or right-hemisphere dominance in brain connectivity. ***CA***

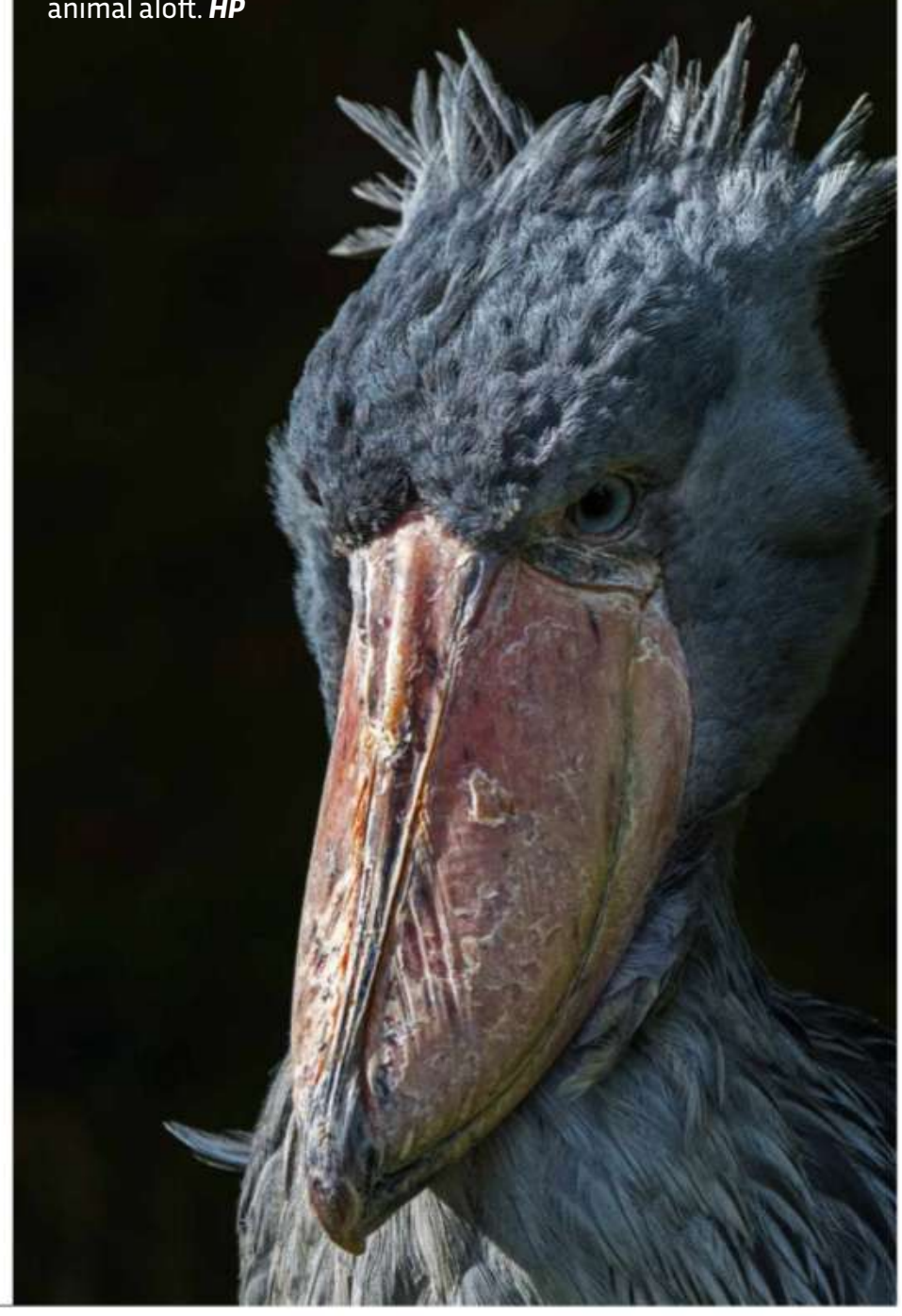
NATURE'S WEIRDEST ANIMALS...

SHOEBILL STORK

At times vilified for its supposedly menacing demeanour, the shoebill stork deserves better. Yes, it's a solitary loner that picks off its prey one at a time. Yes, it has an enormous, shoe-shaped beak that can kill a baby croc or wrangle a lungfish. And yes, its stare is somewhat intense – think Paddington Bear meets Vinnie Jones. It also doesn't help that the bird is physically intimidating. This freshwater swamp specialist from eastern Africa stands over a metre tall, has a wingspan of up to 75cm, and its sharp, clog-shaped bill grows up to 24cm long.

It's also slow, purposeful and utterly relentless. Shoebills are stealth predators. They can stand motionless for hours, before attacking, shaking, crushing and then swallowing their prey, and yet, this relative of the pelican is so much more than some villainous caricature.

For one thing, it poos on its own legs. Not so scary now, eh? Known as urohidrosis, it's a messy but deliberate habit that helps the bird to stay cool. The shoebill is similarly nonconformist in the air, where it has one of the slowest flapping rates of any bird. It takes just 150 beats per minute to keep this impressive animal aloft. ***HP***



LAURA JACKSON, NORFOLK

HOW DO YOU THICKEN A SAUCE?

There are a few ways to thicken a sauce. To add texture to meat juices, you can simmer to allow some water to evaporate before simply whisking in fat to make an emulsion.

You can also add gelatine, which comes from animal collagen and is almost entirely protein. This can come from stock made from boiling chicken scraps. When heated, gelatine's proteins unravel then interweave, causing the liquid to thicken but not solidify. When cooled, the protein strands line up and twist around each other to create a firm gel.

Wheat flour is commonly used to thicken sauces using a process called starch gelatinisation. The flour grains contain partially crystalline granules of starch, which comprises chains of sugar molecules strung together. The secret to starch's thickening success is its ability to absorb water and form a gel. Heating breaks the bonds between the starch molecules, freeing them up to bond and trap water.

Many sauces start as a roux, a smooth paste made from equal parts of flour and fat, such as melted butter or oil. To make a roux, heat the fat then stir in the flour. For a nutty flavour, continue to cook the roux until it is golden brown. The fat coats the flour particles, preventing them from clumping together so that the starch is fully available to gelatinise. Adding liquid while heating causes the starch granules to swell and begin the thickening process. The granules eventually burst open to release starch into the liquid, unleashing more thickening power. Stir the sauce continuously so that the starch doesn't settle at the bottom of the pan to create a lumpy mess.

For a white sauce with a pouring consistency, try 15g plain flour, 15g fat and 250ml milk. For a thicker sauce, you could increase the amounts of flour and fat to 25g while keeping the milk at 250ml. ***ED***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

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WHY DO ANIMALS MIGRATE?

You may have heard about some of the animal kingdom's epic migrations, such as humpback whales travelling from the poles to the equator, or hundreds of thousands of monarch butterflies arriving in Mexico every winter. Many animals make long, treacherous journeys year after year, so why do they go to all that effort?

Many birds, mammals, fish, reptiles, amphibians, crustaceans and insects migrate, and they usually do it to find food, a safe place to breed, or a suitable climate. For example, European swallows migrate south every winter to Africa or Asia where the climate is warmer, and food is more plentiful. Flying 320km a day, they use fat reserves to avoid starvation on their long journey. Another famous migration is that of wildebeest in the Serengeti, which follow the seasonal rains that nourish the grasses on which they graze.

But not all migrations are seasonal: Atlantic salmon spend most of their lives in the sea, and when it is time to reproduce, they travel thousands of kilometres to return to the exact river where they were born. A study published in 2021 found they can travel up to 2,940km to return to their birth river, all to ensure their offspring get the best start in life.

Although their feats of endurance are incredible, animals that migrate tend to be more vulnerable to climate change, deforestation and habitat fragmentation because they rely on multiple habitats, across countries or even continents, to survive or complete their life cycle. *CA*

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ANDREW WHITE, HULL

WHAT'S THE DIFFERENCE BETWEEN AN OCTOPUS AND A SQUID?

Octopuses and squid are close cousins with much in common. Both groups are remarkably brainy molluscs, especially compared to their relatives including snails, clams and slugs. They have complex nervous systems which, among other things, intricately control their colour-changing skin. A recent study of Humboldt squid suggested they have a simple language of patterns displayed across their bodies. Another piece of research on oval squid in Japan has recently shown that, just like octopuses, squid can also match their body colour to their surroundings to hide from predators.

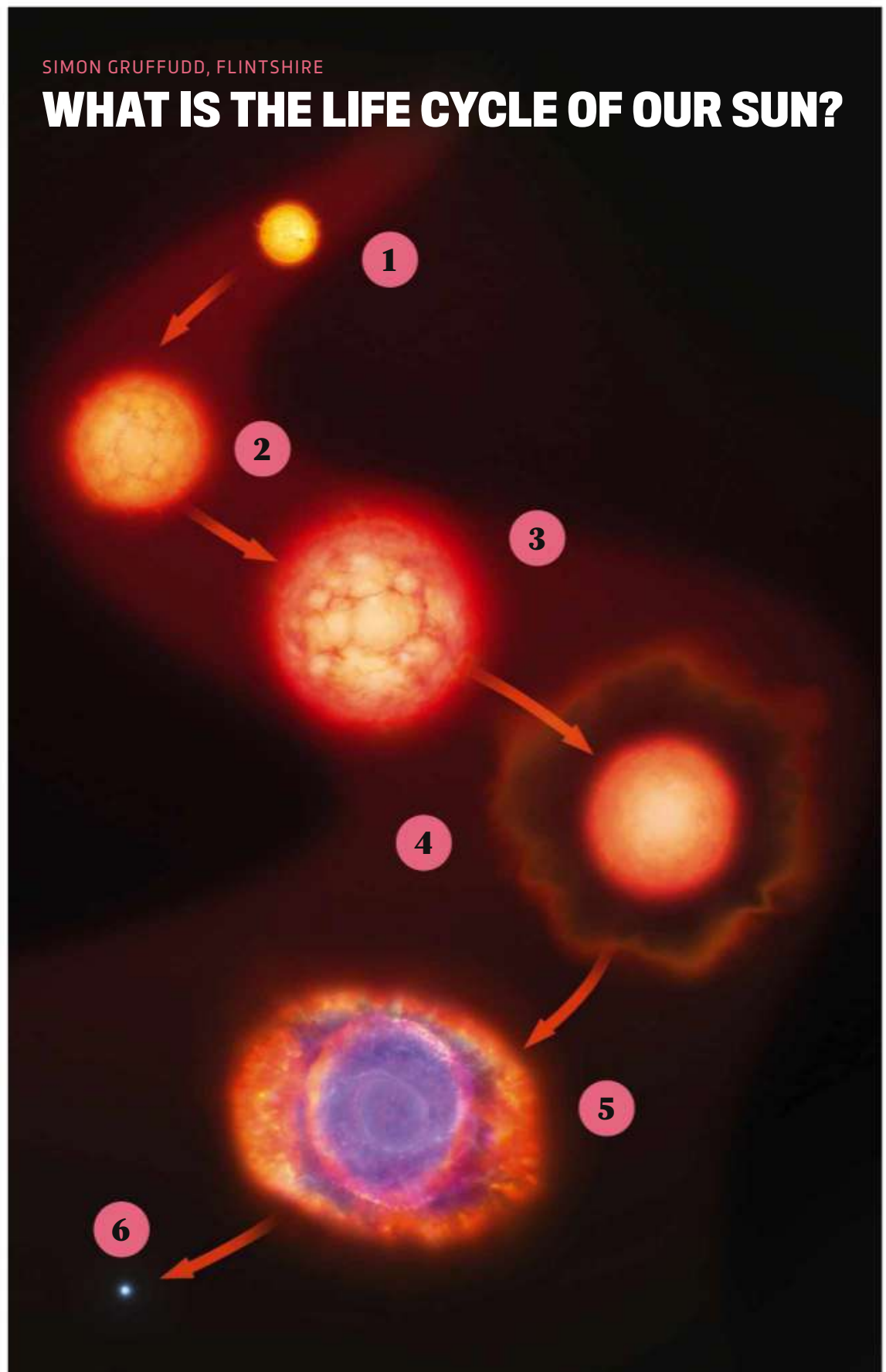
There are, however, plenty of differences between octopuses and squid. To tell them apart, all you need to do is count their numerous appendages. Octopuses have eight arms with sensitive suckers arranged all the way to the tip. Meanwhile, squid have eight arms plus an additional pair of limbs with suckers just at the ends. These are tentacles that they shoot out, like a chameleon's tongue, to grab and drag in prey.

There are around 300 species of octopuses, and a similar number of squid which occupy different ocean habitats. Most octopuses live close to the seabed, with a few exceptions like blanket octopuses and argonauts. Usually, they're solitary and often thoroughly antisocial (in aquariums they tend to eat each other). The exceptions are two locations in Australia, nicknamed Octopolis and Octlantis, where octopuses have been found living rather awkwardly together in close neighbourhoods. In contrast, squid swim through open seas, often in coordinated shoals.

Octopuses and squid also differ in the way they produce offspring. For octopuses, male-female pairs mate at arm's length. The female then lays her eggs in a safe spot on the seabed and watches over them until they hatch. Squid mate in groups and leave their eggs to fend for themselves, stuck to seaweed, rocks and corals. ***HS***

SIMON GRUFFUDD, FLINTSHIRE

WHAT IS THE LIFE CYCLE OF OUR SUN?



1. Hydrogen-burning phase
Nuclear fusion is converting hydrogen into helium, releasing energy and radiation we see as sunlight. This phase began around 4.6 billion years ago and in around 3.5 billion years from now, the Sun will be around 40 per cent brighter. On Earth, the oceans will boil, the ice caps will melt, and the atmosphere will be stripped away.

2. Subgiant phase
In around five billion years, the core will start to contract and become denser. As the temperature rises, the remaining hydrogen will ignite and push the outer layers outward, causing the Sun to expand to two to three times its current size.

3. Red giant formation
Once all the hydrogen is used up, helium will start to fuse, causing the Sun to expand and cool. It will dim, become redder and swell in size to around the position of Earth's orbit.

4. New red giant
The Sun's core will get smaller and hotter until the helium ignites and burns with intense ferocity, producing a helium flash. As the helium continues to burn, the Sun will expand again.

5. Planetary nebula
As the helium is used up, the outer layers will be pushed further out into space, creating a glowing cosmic cloud.

6. White dwarf
After the outer layers have dissipated, a hot, dense core will remain. It will take tens or perhaps hundreds of billions of years to cool. When all the remaining heat and light energy is expended, the Sun will fade into a lifeless black dwarf.

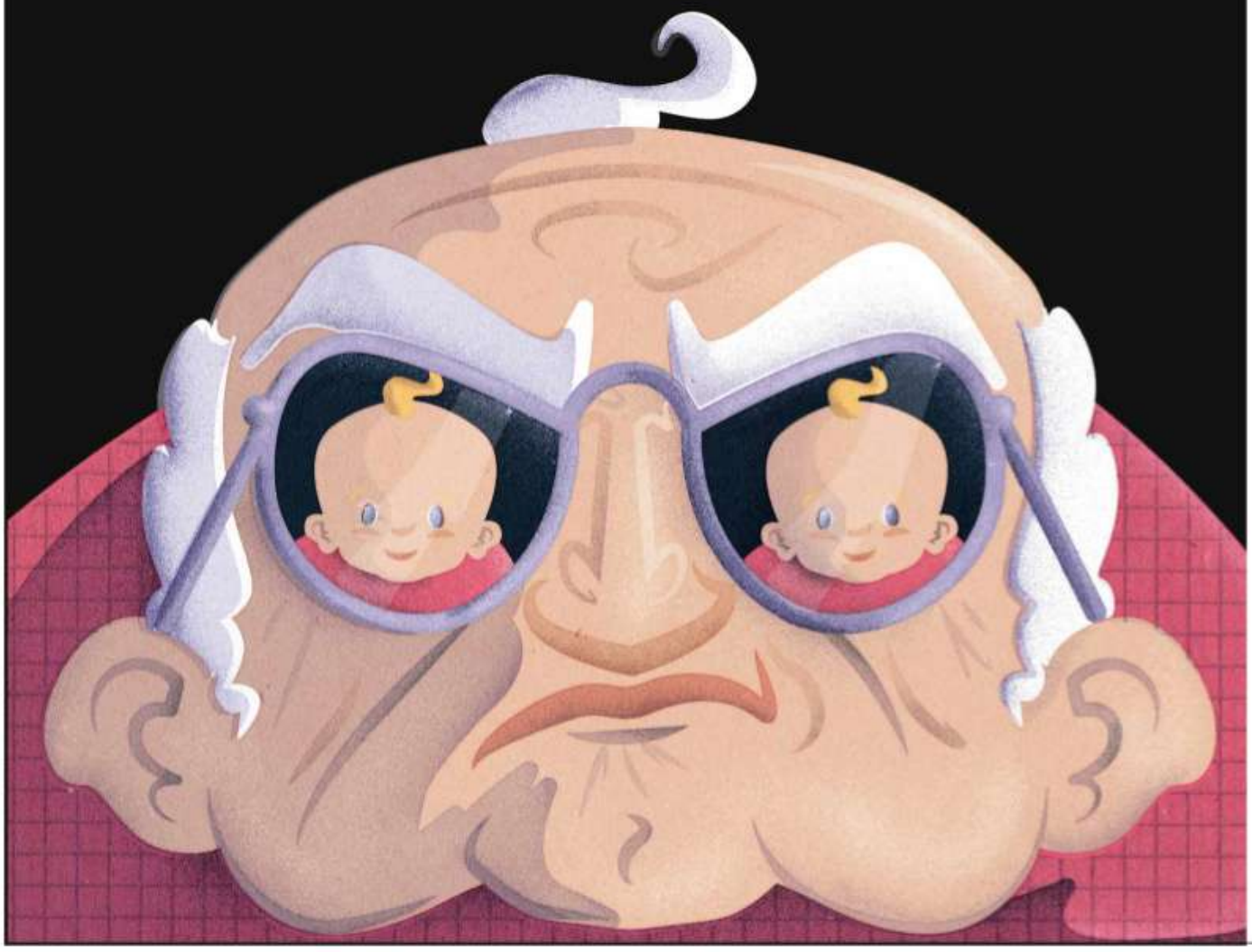
DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY *SCIENCE FOCUS* EXPERTS

DO WE GET MORE BITTER AND CYNICAL AS WE GET OLDER?

You're alluding to an unkind stereotype of older people, but does it have any truth to it? In personality terms, the evidence shows that, on average, the older we get, the more closed-minded we tend to become. We are less willing to see alternative perspectives or explore new experiences. Importantly, however, another way that our personalities tend to mature in old age is that our neuroticism decreases and our agreeability increases. That is, older people tend to be calmer, warmer, friendlier and more trusting than they were when they were younger – which is hardly consistent with the stereotype of an ageing curmudgeon. In fact, a Swiss study of people over 80 years old noted their remarkable composure and nonchalance toward old age – a trait the researchers called 'senior coolness'.

Another perspective comes from the Danish-American psychoanalyst Erik Erikson, whose eight-stage theory of life development described the final stage – from roughly 65 years old and upwards – as a psychological battle between integrity and despair. If older people view their lives with disappointment and regret, he said, then despair will win, thus fuelling bitterness. In contrast, older people who recognise they did the best they could and see their lives with acceptance and a sense of meaning, then they avoid bitterness and get to enjoy feelings of wisdom instead. Maybe that's the 'coolness' the Swiss researchers observed! ***CJ***



RYAN YOUNG, MIDDLESBROUGH

IS IT TRUE THAT YOU CAN BITE THROUGH A HUMAN FINGER AS EASILY AS A CARROT?

Definitely not. Go and get a carrot from the fridge now and try it yourself. Bite the carrot and then bite your own finger just as hard. It will hurt, but you won't even break the skin on your finger. Could you bite your own finger off, if you really wanted to? At the knuckle, possibly, but it would be very difficult. A 2012 study of hand injuries from electric windows in cars found that an average of 1,485 Newtons of force was required just to fracture a human finger. This is about twice the maximum bite force you can exert and about 10 times the force exerted when chewing normally. ***LV***

STEPHANIE LEE, BRISTOL

SHOULD I TAKE MY SHOES OFF INSIDE THE HOUSE?

Keep them on, if you can stomach knowing what they carry on their soles. Tests have shown that shoes carry a host of faecal bacteria – including *E. coli* – which could come from the floors in public toilets as well as from dog poo. One study carried out at the University of Arizona, US, suggested that over 90 per cent of the bacteria from your shoes then transfer to the floors in your home. Shoes can also traipse in carcinogenic chemicals from roadside dust, along with problematic pesticides from lawns. Of course, some dirt is good for you, but you can always go in the garden to be exposed to germs. ***ED***

KAREN SCOTT-MARTINET, NEW HAMPSHIRE

WHAT'S ON THE OTHER SIDE OF A BLACK HOLE?

A black hole is defined by its 'event horizon', the imaginary membrane that marks the point of no return for in-falling light and matter. If the Sun were to become a black hole – which is impossible since it is not massive enough – the event horizon would only be six kilometres across.

The biggest supermassive black holes are tens of billions of times more massive than the Sun and are in the hearts of all galaxies, though nobody knows why. These supermassive black holes have event horizons bigger than the Solar System.

If you crossed the event horizon and entered a black hole, space-time would be so distorted that time would become space, and space would become time. This is why you cannot avoid the monstrous infinite-density 'singularity' that lurks like a black widow spider at the heart of a black hole: it no longer exists across space, but across time. It exists in the future, and you can no more avoid it than you can avoid tomorrow.

As for what exists on the other side of the singularity, some have speculated that this is a gateway to far-flung parts of our Universe or even other universes. The truth is that a singularity in a theory marks the breakdown of that theory, and the point at which it has nothing more sensible to say.

In order to truly understand what happens at the heart of a black hole and whether 'What's on the other side?' is a meaningful question, we will need a better theory of gravity than Einstein's – a 'quantum' theory of gravity. Finding one of these is one of the supreme challenges of science! ***MC***

QUESTION OF THE MONTH

PAMELA FLOWER, VIA EMAIL

GIVEN THE IMMENSE TIME PERIOD THAT DINOSAURS EXISTED FOR, WHY DID NONE OF THEM DEVELOP SENTIENCE?

One thing that sets humans apart from other animals – as far as we know – is that we are sentient. Not only do we have large brains and keen intelligence, but we are self-aware. We are conscious: we sense the world around us in an advanced way, and know that we exist, and that others exist.

Our species has been around for just a few hundred thousand years, a newcomer on the geological scene. So why didn't dinosaurs develop sentience during their evolutionary run that exceeded 150 million years? First off, we assume they didn't, because they didn't leave records of things like writing, language and other sentient thought processes in the fossil record. But we now know from CT scanning of fossil skulls that many dinosaurs had very large brains.

Could these large brains have eventually become sentient? Maybe, if the end-Cretaceous asteroid impact didn't knock out dinosaurs in their prime and pave the way for our mammalian ancestors. ***SB***

WINNER

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ALAMY, GETTY IMAGES X2 ILLUSTRATIONS: DAN BRIGHT

THE EXPLAINER

TINNITUS

WHAT IS TINNITUS?

Tinnitus is often thought of as the 'ringing in the ears' that we might have temporarily after going to a loud concert. However, as many as 1 in 25 people have tinnitus that affects them long-term, impacting their daily lives and often coming hand-in-hand with mental health conditions, such as depression. But it's not always heard as a ringing, and those who have it may describe it as buzzing, humming or whooshing. For some people, the sound pulses in time with their heart beat – this is known as 'pulsatile tinnitus'. In general, tinnitus is a sound that comes from within; it doesn't originate from an external source like the radio or washing machine. Most often, it's a signal that the affected person perceives as a sound, but is generated in the brain. More rarely, it can be a 'real' and sometimes detectable sound coming from the body – like muscles or blood vessels – near to the ears. This is known as 'somatosound'.

WHAT CAUSES IT?

Detectable sound, or somatosound, can be related to high blood pressure. But in the majority of tinnitus patients, it is harder to explain what is happening. We know that it is more than likely caused by damage or changes to the ear, or to the the auditory cortex, which is the part of the brain that deals with hearing. Sometimes the damage comes from repeated exposure to loud noise, or simply growing older. One aspect that makes the cause difficult to discern is that people don't always hear the sound that they associate with tinnitus until after the damage that caused it occurred. Research suggests the signal is initially masked by the brain, but when other triggers, such as stress, come into play, this in-built 'noise cancellation system' breaks, and the signal is perpetuated in the brain by changes in the auditory cortex.

WHO GETS TINNITUS?

There are several groups of people who are more likely to get tinnitus. One is those with hearing loss; by some estimates, 9 out of 10 people who get tinnitus also have some level of hearing loss. Tinnitus is common in musicians, military personnel – army veterans are more than twice as likely as non-veterans to have tinnitus – and, less obviously, pregnant people. It's thought that the changes in blood volume and pressure, water retention, and circulating hormones that occur with pregnancy may affect tissues or nerves in the ear, altering the signals that are sent to the brain. There is also evidence from a 2021 study suggesting that COVID-19 can cause tinnitus, but it's unclear whether the ears or brain are affected directly, or whether the tinnitus is triggered by emotional stress, like during the pandemic.

WILL IT GO AWAY ON ITS OWN?

Sometimes. Mild cases often clear up within a matter of days – as in the example of going to a loud concert. However, scientific studies are more likely to be focused on people for whom the symptoms have persisted for longer. According to UK researchers who reviewed evidence from studies published between 1992-2016, symptoms tend to improve the most in the first four months after the person initially notices them, with no apparent change after that. Many people have to learn to live with tinnitus, leading to serious impacts on their quality of life and mental health. Some studies suggest that having tinnitus can make conditions like depression and anxiety worse. It is also very common for people with tinnitus to develop hyperacusis – increased sensitivity to normal noise levels – which causes further stress and anxiety.

HOW IS TINNITUS TREATED?

In most cases, there is no cure. Medication consists of antidepressants and anti-anxiety pills rather than drugs that directly treat the tinnitus. Cognitive behavioural therapy can help people reframe negative thoughts and emotions about the sound and improve their wellbeing, while education and counselling provide reassurance that the sound isn't a symptom of anything sinister.

Some find benefit in sound therapy, which uses white noise, music or sounds played through smartphone apps, to mask tinnitus. For those with hearing loss, masking sounds can be played through hearing aids, and while cochlear implants can improve tinnitus, they're not offered to everyone. Nerve and brain stimulation are potentially exciting new therapies. There is good evidence that implants similar to those used in epilepsy could help, although these involve brain surgery.

A safer option is stimulating branches of the vagus nerve – which extends into the brain's auditory cortex – at the ear or neck, with studies showing reduced distress and a slightly reduced perceived loudness of the tinnitus. Meanwhile, Australian researchers are working on brain stimulation using electrodes strapped to the outside of patients' heads, claiming to have temporarily silenced tinnitus in some people for several days.

by **HAYLEY BENNETT**
Hayley is a science writer based in Bristol, UK.

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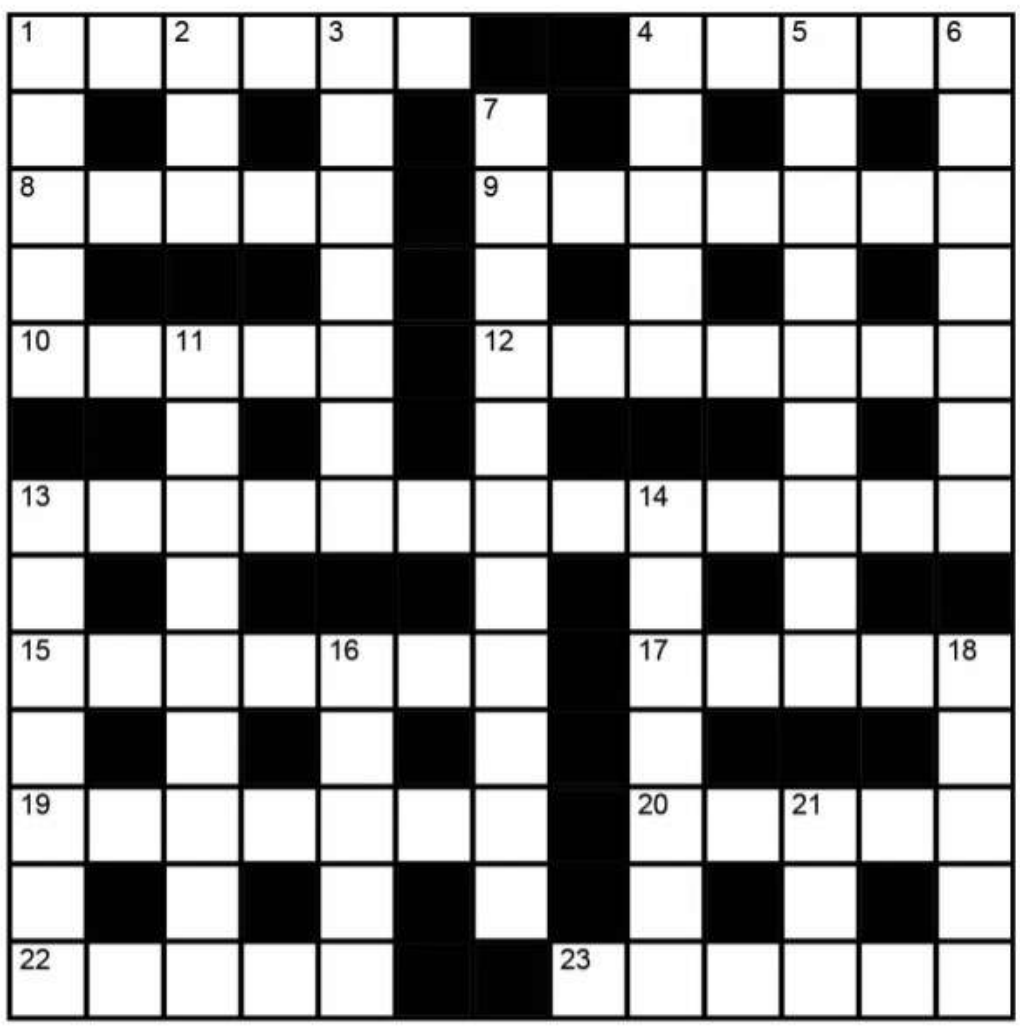
CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Husband and son sit around university (6)
4 Quickly avoids lowest scores (5)
8 Consider a topiarist to have a muse (5)
9 Soldiers, old, left in shade (7)
10 Put off animal around junction (5)
12 Huge growth in socialist club (7)
13 Overall owner finding ancestor firm (6,7)
15 Country road, meandering around knight and artist (7)
17 Chicken, say, in a film (5)
19 Incorrectly rated the French lever (7)
20 Opening move not initially in range (5)
22 Artisan's mother and child (5)
23 Upper classes sample information first (6)

DOWN

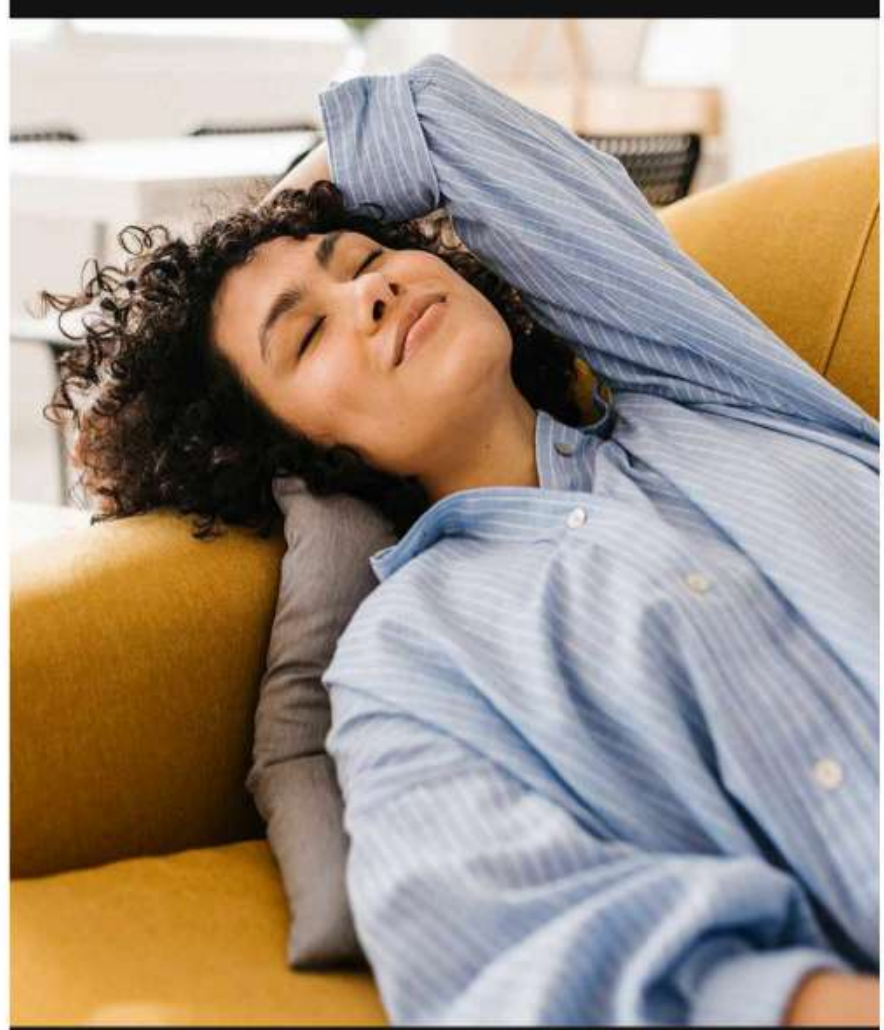
1 Wimbledon favourite has time to get horse (5)
2 Removal includes eggs (3)
3 Betting gold travelled in pouch (7)
4 Challenged father, about to go in (5)
5 Commonplace to shout about barking at sumo (9)
6 Idyll so wrong, in a rigid way (7)
7 Respected having increased in value (11)
11 Tried moving head in exhaustion (9)
13 Christmas show gets Henry married, in spirit (7)
14 Chap conceals conflict in hazardous program (7)
16 Sculptor finding staff at home (5)
18 Irritable friend of Mole's (5)
21 Flying mammal making a racket (3)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

HOW TO NAP LIKE A GENIUS



GETTY IMAGES

PLUS

ECHOLOCATION

It's how bats and whales find their way around, but how does it work?

I'M JUST A LOVE MACHINE

Why we love some robots but not others (and the reason everyone hated Clippy)

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POPCORN SCIENCE

How does Thor's hammer work?

Is it security coded, or is it simply tampering with physics?

by **STEPHEN KELLY**

According to comic book legend, the hammer of Thor, Mjölnir, can only be lifted by those who are deemed worthy enough to wield it. Now, with *Thor: Love And Thunder* due for release, this has inevitably led to questions. What makes someone 'worthy'? How does the hammer stop the likes of the Hulk from lifting it? And if even the Hulk cannot lift it, how much must it weigh? It's a debate so enduring that it made its way into 2015's *Avengers: Age Of Ultron*, where all of the Avengers took turns trying (and failing) to lift the hammer off a table. "The handle's imprinted, right?" suggests an annoyed Tony Stark. "Like a security code?"

James Kakalios, a physics professor at the University of Minnesota, and author of *The Physics Of Superheroes*, has spent more time than most thinking about Thor's hammer. So much so, in fact, that his theory for how it works was cited by Bruce Banner himself in an issue of the 2012 comic *The Indestructible Hulk*. For a start, Kakalios suggests that Stark wasn't that far off with his idea of the hammer's handle featuring a fingerprint scanner.

"The science of the Asgardians is so advanced that to us it would seem like magic," he says. "It makes sense that Mjölnir would possess a form of artificial intelligence that, when you grab the handle, uses some sort of biosensor to scan whether you're worthy." He uses a scene from the first Thor movie to illustrate his point. "Odin banishes Thor, after whispering to Mjölnir, 'whoever holds this hammer, if they be worthy, shall possess the power of Thor'. So basically Odin has administrator rights to rewrite the hammer's operating code."

But even if that was true, how does Mjölnir also repel the unworthy by making itself impossible to lift? Kakalios's Bruce-Banner-approved theory pivots around gravitons. These are fundamental particles that have not yet been confirmed to exist on Earth, but could exist in the scientifically advanced society of Asgard.

"No one has observed a graviton yet," he says, "but it is believed to be the quantum mediator of the gravitational force; much like photons of light are the quantum excitation of the electromagnetic field."

Kakalios's theory is that when Mjölnir is grabbed by someone it has deemed unworthy, it emits gravitons to make the hammer a heavier weight than the individual can lift. This, Kakalios says, explains why the hammer does not fall through the table in *Avengers: Age Of Ultron* – because it is able to use gravitons to adjust its weight and nullify whatever force is being exerted on it.

"It will only emit those excess gravitons while you're trying to lift it," says Kakalios. "Let's say the hammer weighs 40 pounds. It exerts a force of 40 pounds on the table and the table pushes back with a weight of 40 pounds. So the hammer doesn't move. You then try to lift it off the table with a force of 80 pounds. You should be able to because 80 up is greater than 40 down. But if the hammer at that moment knows how much force you're exerting, it could emit gravitons so now it weighs 80 pounds. Your 80 and its 80 balance out. The moment you let go, it stops emitting the gravitons and goes back to weighing 40 pounds, meaning it can sit on the table just fine."

Or, of course, it could just be magic. **SF**

VERDICT

Mjölnir's traits might be weird, but it can all be explained by Asgardian physics... even if their physics is different from ours.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATIONS: ADAM GALE MAIN ILLUSTRATION: SAM BREWSTER

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

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